SOUTH DAKOTA FISHERIES

Influence of Size-and-Date at Stocking, Imprinting Attempts and Growth on Initial Survival, Homing Ability, Maturation Patterns and Angler Harvest of Chinook Salmon in Lake Oahe, SD

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Influence of Size-and-Date at Stocking, Attempts and Growth on Initial Survival, Homing Ability, Maturation Patterns and Angler Harvest of Chinook Salmon in Lake Oahe, SD

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Preface

Information summarized in this report was collected and analyzed from April of 1987 through April of 1997. Copies of this report and references to the data can be made with permission from the authors or the director of the Division of Wildlife, South Dakota Department of Game, Fish and Parks, Foss Bldg. 523 E. Capitol, Pierre, SD 57501-3182.

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Executive Summary

In order to determine the effects of imprinting attempts, size and date at stocking, and stocking location on the performance (survival, growth, maturity patterns, homing ability) of chinook salmon stocked into Lake Oahe, South Dakota, a number of studies using coded-wire-tagged (CWT) chinook salmon were conducted from 1987 through 1996. Approximately 500,000 chinook salmon, in 18 study groups, were implanted with coded wire tags from 1987 through 1993. Coded-wire-tagged chinook salmon were recovered at the Whitlocks Bay spawning station and from the angler harvest.

Attempts at using morpholine to imprint chinook salmon to the Whitlocks Bay spawning station were unsuccessful. Holding chinook salmon at the spawning station prior to stocking did not improve survival to recruitment into the fishery or homing ability to the spawning station of salmon held at the station, compared to salmon directly stocked into Whitlocks Bay.

For chinook salmon groups stocked as spring-age-0 fish, from the same brood year, fish stocked at a larger average size, later in the spring, contributed more to the fishery and spawning runs than did fish stocked at a smaller average size, a month earlier. Even when stocked on the same date, as for the 1992 brood year, increasing the size of fish at stocking resulted in an increased contribution to the fishery and spawning runs, based on numbers stocked. In general, chinook salmon groups, stocked as spring-age-1 fish, contributed more to the fishery and spawning runs at the Whitlocks Bay spawning station than did spring-age-0-stocked fish from the same brood year, based on numbers stocked.

Raising male chinook salmon to spring age-1 before stocking into Lake Oahe increased precocialness, for both the 1987 and 1989 brood years. Males from these stockings did not contribute substantially to the fishery with mortality near 100% in the seven months after stocking. Raising female chinook salmon to spring age 1 before release resulted in a later onset of maturity, as the percentage of the 1987-brood-year females maturing at age 4 increased. If survival until recruitment to the fishery can be improved by raising chinook salmon until fall age 0 or spring age 1 before stocking, the same contribution to the population could be made by stocking fewer, older fish.

The spring-age-1-CWT group from the 1989-brood year had higher total returns to the spawning station than did spring-age-0 or fall-age-0-stocked fish, when returns were weighted by production costs. However, almost all the males from this CWT stocking group returned to the station at age 2. No differences existed in total returns to the fishery between 1989-brood-year-CWT groups, when numbers returned were weighted by production cost ($P>0.25$ in all cases). Therefore, if the same amount of money was spent raising fish until spring-age-0, fall-age-0 or spring-age-1 before stocking, even though the numbers stocked were different, the stockings would contribute equally to the fishery.

Differences in average size at stocking of spring age-0-CWT groups did not affect maturation patterns. As previously discussed, raising male chinook salmon to spring age-1 before stocking into Lake Oahe resulted in an increase in the percentage of males maturing at age 2 to 98-100%. Stocking chinook salmon at fall age 0 did not increase the percentage of males maturing at age 2. Fall-age-0 stockings did not cause an increase in precocialness of males but did result in a higher percentage of females maturing at age 4.

Fish from fall-age-0 and spring-age-1 stockings tended to be smaller on average, at age at maturity, than fish from spring-age-0 stockings from the same brood year. Females from the 1989-brood-year-spring-age-0-CWT group generally matured a year earlier than females from the 1989-brood-year-fall-age-0 and spring-age-1 stockings.
For chinook salmon stocked as spring-age-0 fish, positive correlations existed between the percent of males or females in a year class maturing at the youngest age maturity is generally reached (age 2 for males, age 3 for females) and age-1 and older *Wr* in the August suspended gill net survey ($P=0.04$, $r=0.78$ and $P=0.001$ and $r=0.96$, respectively). A positive correlation also existed between the percentage of female chinook salmon stocked as spring-age-0 fish that matured at age 3 and the mean number of eggs per female at the Whitlocks Bay spawning station ($P=0.001$, $r=0.95$). Instead of a positive linear relationship between growth and maturity, a threshold size and/or condition level must be attained before the onset of maturity is triggered.

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Introduction

In the early 1970's, attempts were made to develop a salmonid sport fishery, in Lake Oahe, South Dakota, that would utilize available coldwater habitat and diversify the fishery. Introductions of kokanee salmon, bonneville cisco and opossum shrimp were made with the objective of establishing a coldwater prey base for a large predator species. These introductions were unsuccessful. However, rainbow smelt stocked into Lake Sakakawea in 1971, had become abundant in Lake Oahe by 1977. Chinook salmon had also reached Lake Oahe as early as 1979 from Lake Sakakawea. In October 1981, Department of Game, Fish and Parks personnel collected 100,000 chinook salmon eggs from 54 female salmon that had congregated in Whitlocks Bay. The 1981 egg-taking operation resulted in 31,280 smolts being stocked at Whitlocks Bay in April 1982 along with an additional 260,870 smolts produced from Lake Michigan eggs. From 1982 through 1988, the majority of chinook salmon stocked into Lake Oahe were from eggs collected at the Manistee River on Lake Michigan.

A popular chinook salmon fishery has developed and in 1996, chinook salmon were second to walleye in terms of estimated fish harvested, at 33,077 fish. Currently, between 300,000 and 400,000 chinook salmon are annually stocked into Lake Oahe as spring-age-0 fish.

To ensure annual egg production needs would be met, the Whitlocks Bay spawning station was constructed in 1984 for the purpose of collecting and spawning mature chinook salmon. Concern over the possible introduction of chinook salmon eggs carrying bacterial kidney disease into South Dakota was an added incentive for becoming self reliant in terms of chinook salmon egg needs.

In order to better understand the migratory nature of chinook salmon stocked into Lake Oahe and the effects of size and date at stocking and stocking location on the performance (survival, growth, maturity patterns, homing ability) of stocked chinook salmon, a number of studies using coded-wire-tagged (CWT) salmon were conducted from 1987 through 1996.

Each of the studies listed in this report were designed to meet at least one of the following objectives:

1. To determine effects of chemical imprinting attempts on the homing ability of two sizes of chinook salmon to the Whitlocks Bay spawning station.

2. To evaluate effects of stocking techniques on homing ability of spring-age-0-stocked chinook salmon by comparing return rates to the Whitlocks Bay spawning station of smolts held at the station with those directly stocked into Whitlocks Bay.

3. To compare return rates of chinook salmon to the Whitlocks Bay spawning station and the creel for fish stocked at different sizes and/or different dates.

4. To evaluate the performance of chinook salmon raised in hatcheries until fall age-0 or spring-age-1 before stocking compared with standard spring-age-0-stocked salmon.

Study Area

Lake Oahe is a 150,000 h, mainstem, Missouri River, storage reservoir that was constructed to alleviate flooding, generate electric power, support water development projects and provide recreation. Lake Oahe is managed for coolwater and coldwater game fish species including walleye, northern pike, smallmouth bass, rainbow trout and chinook salmon. Physical characteristics of Lake Oahe appear in Table 1.

Table 1. Physical characteristics of Lake Oahe.

Oahe Dam Closed in:	1958	***Reservoir length:**	372 km
Elevation at full pool:	1617 msl	***Shoreline length:**	3620 km
***Surface area:**	150144 h	**Drainage Area:**	630639 km^2
***Water volume:**	2.9×10^{13} l	***Average Depth:**	18.3 m
***+Coldwater habitat:**	47755 h	***Maximum Depth:**	62.5 m
Trophic Status:	olig/meso	**MEI:#**	28.4
Shoreline Development Index:	26.4	**Storage Ratio:**	1.05

*Denotes values for water elevation at full pool.
+Denotes volume of water ≤15°C.
#MEI: Morpho-edaphic index (Ryder 1982)

Whitlocks Bay is located approximately 128 river kilometers upstream of Oahe Dam as illustrated in Figure 1. The Whitlocks Bay spawning station consists of a fish ladder, four, 13.7-m by 2.4-m by 1.2-m concrete holding raceways, a crowding raceway, spawning building and a water supply system capable of delivering a maximum of 10,000 l/min. Water is pumped from Whitlocks Bay into the raceways where it gravity flows through the raceways and back down the fish ladder into the reservoir.

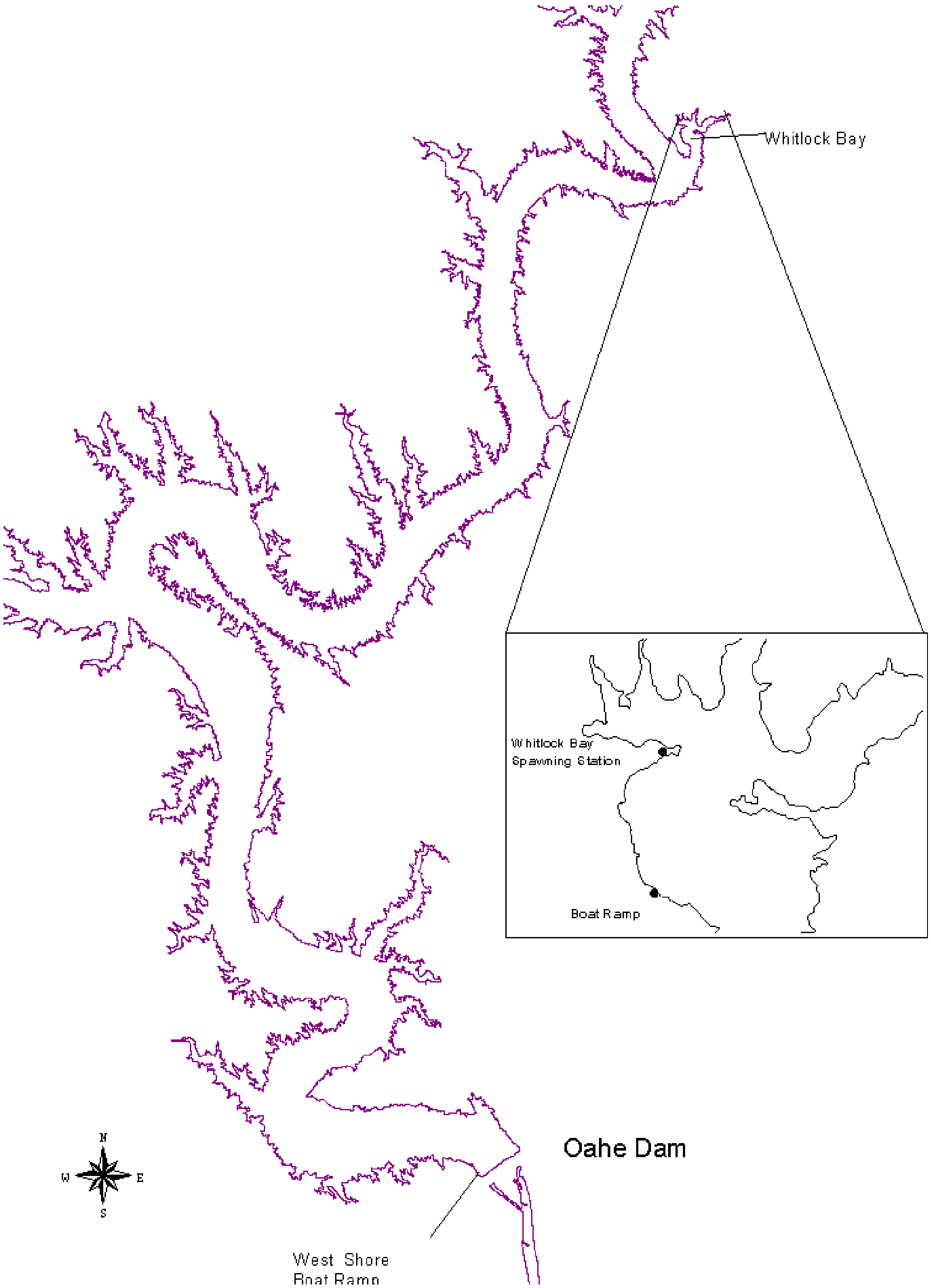

Figure 1. Lake Oahe study area.

Methods

Egg-Take and Rearing

Chinook salmon eggs, once fertilized, were water hardened prior to transport to state fish hatcheries where they were placed in incubation trays until hatching. Chinook salmon fingerlings were then raised intensively until coded-wire tagged.

Coded-Wire-Tagging

Chinook salmon from treatment groups were generally injected with coded-wire-tags at state fish hatcheries during April, at a size larger than 4.5 g. Chinook salmon were placed into shallow pans of water and anesthetized with tricaine methanesulfonate (MS-222). After the MS-222 had taken effect, clippers were used to remove the adipose fin from each fish. Chinook salmon were then injected with a CWT using either a Northwest Marine Technologies MKII or MKIV tag injector. After tag injection, chinook salmon were passed through a quality control device (QCD) and fish not containing a tag were run through the tagging procedure again. Coded-wire-tagged chinook salmon were then returned to hatchery tanks or raceways. Prior to stocking, a sample of chinook salmon from each treatment group were examined for CWTs to determine tag retention rates.

Imprinting and Stocking

Based on the programming and production capabilities of South Dakota's three fish hatcheries, a number of size and age combinations exist for rearing and stocking chinook salmon. The four rearing options used for coded-wire-tag groups in this study are shown in Figure 2. Detailed descriptions of rearing, stocking and imprinting treatments of CWT treatment groups appear in the tables describing treatment group performance for each brood year. A summary of treatments for all CWT groups appears in Appendix 1.

Coded-Wire-Tag Recovery

Coded-wire tags were recovered from chinook salmon in the angler harvest and from fish ascending the ladder at the Whitlocks Bay spawning station. When the coded-wire-tagging program was initiated in 1987, news releases were generated and signs describing the coded-wire-tagging project were posted at boat access areas and local bait shops. Anglers were asked to turn in the heads of all salmon caught that were missing an adipose fin. The Missouri River Fisheries Center and local bait shops served as collection locations for chinook salmon heads from adipose-clipped salmon. From 1993 through 1997, a salmon and trout creel survey was conducted at the West Shore lake access area, near Oahe Dam. During these years, the majority of the CWTs recovered from angler- caught fish were recovered at West Shore (Figure 1). From 1987 through 1996, snouts were

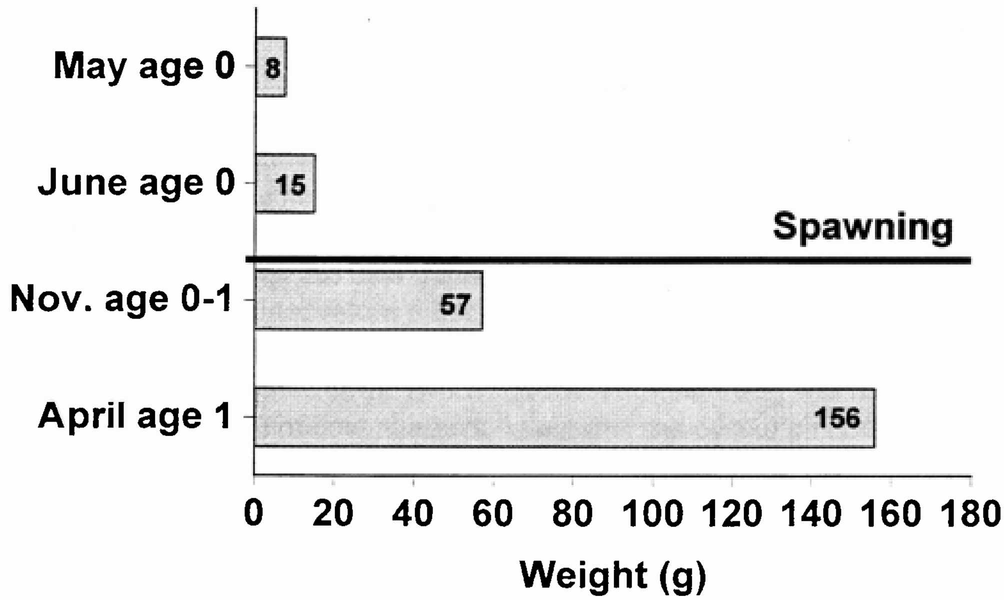

Figure 2. Fall chinook salmon rearing options for South Dakota fish hatcheries. Numbers inside of bars are approximate average weights (g) of chinook salmon at stocking after being reared to the specified age.

were removed from all adipose clipped chinook salmon ascending the Whitlocks Bay spawning station ladder and fish length, weight and sex recorded.

Age Designation

In this report, ages of chinook salmon after stocking are based on the premise that salmon become a year older during the spawning season. Therefore, a chinook salmon stocked one year as a spring age-0 fish would be age-1 during the spawning season of that same year, age 1+ the summer of the following year and age 2 during the spawning season of the following year. Male chinook salmon that mature early (age-2) are commonly referred to as "jacks". Males maturing as jacks are considered age-1+ fish the summer before they spawn and age-2 fish during the spawning season.

Data Analysis

Primary data analysis involved the number and sex of CWT chinook salmon returning to the Whitlocks Bay spawning station at maturation and the number of CWT salmon returning to the fishery each year and overall. Numbers of CWT chinook salmon returning to each location, each year and overall, were compared between CWT groups from the same brood year. It is believed that the percentage of a year class of chinook salmon from a CWT group returning to the Whitlocks spawning station and the angler comparisons of CWT groups from different brood years were not made as these groups probably experienced different return and reporting percentages at each age throughout their life.

The number of CWT chinook salmon returning to the Whitlocks Bay spawning station or the fishery was weighted by number and kilograms stocked, when making comparisons between treatment groups. Because number and kilograms of fish stocked differed among treatment groups, this data transformation was necessary to allow return numbers to be compared. Weighted return numbers to the Whitlocks Bay spawning station and the fishery were statistically compared using chi square analyses. For these chi square analyses, the average value of the two weighted return numbers was used as the expected value. A brief example of how numbers, kilograms and cost of chinook salmon returning to the spawning station or the creel were weighted for comparison between study groups is provided in Table 2.

Table 2. An example of the methodology used to weight numbers of fish returning to the Whitlocks Bay spawning station and the creel so numbers returned from study groups from the same brood year could be properly compared. Methodology used for comparing returns based on kilograms or cost of study groups follow the same principles as the weighting methodology used for numbers stocked.

Group 1: 64508 fish at 7.1 g stocked 5/12/88 as spring age 0 fish
Group 2: 53815 fish at 15.1 g stocked 5/31/88 as spring age 0 fish
Ratio of number stocked (Group1:Group2): 1.20

Year	Age	Raw Data Station		Raw Data Creel Survey		Weighted Data Station		Weighted Data Creel Survey	
		Group 1	Group 2	Group 1	Group 2	Group 1	Group 2	Group 1	Group 2
1988	0-1	0	0	2	4	0	**0**	2	**5**
1989	1-2	3	7	18	37	3	**8**	18	**44**
1990	2-3	30	70	39	81	30	**84**	39	**97**
1991	3-4	14	40	26	52	14	**48**	26	**62**
1992	4-5	0	8	5	9	0	**10**	5	**11**
1993	5-6	2	0	0	0	2	**0**	0	**0**
Total		49	125	90	183	49	**150**	90	**219**

Return numbers for group 2 were weighted (multiplied by 1.2) to estimate the number of returns if the same number of fish of group 2 were stocked as group 1.

Comparisons of total return numbers, weighted by numbers and kilograms stocked, were used to determine if differences in survival rates, prior to recruitment to the fishery, existed between CWT groups from the same brood year. Differences between ratios of CWT groups in the fishery and at the spawning station were used to assess which CWT group in a comparison did a better job of homing to the Whitlocks Bay spawning station.

Additional data analysis included weighting return numbers by production costs (spawning, rearing and stocking) of a CWT group, comparing mean weight-at-age at maturation of CWT chinook salmon returning to the spawning station between or among treatment groups, and changes in percent maturation at age between or among treatment groups. Again, only within-brood-year comparisons were made. Weights used were post-spawn weights. Chi-square analyses were used to test for differences in return numbers weighted by cost as previously described for return numbers weighted by number or kilograms stocked. Mean-weight-at-age of maturity of CWT chinook salmon returning to the spawning station were tested for among-year and treatment-group effects using a general linear modeling procedure and a least squares mean procedure to determine where differences existed. Patterns in percent maturation of a treatment group were tested for differences between treatment groups, for each sex, using a chi-square test for differences in frequency distributions. Simple linear regression was used to test for significant correlations between patterns in maturation of fish stocked at spring age-0 and fish growth (mean weight at maturity) and condition (*Wr*; Wege and Anderson 1978, Halseth et al. 1990) and between patterns in indices of growth and condition and rainbow smelt catch per unit effort in the August suspended gill net survey. For all statistical tests, an alpha level of 0.05 was used as the basis for acceptance or rejection of null hypotheses. The Statistical Analysis System (SAS; 1985) for microcomputers was used to perform parametric statistical tests, while SYSTAT (1992) was used to perform nonparametric tests.

Treatments and Results

As previously discussed, the objectives of coded-wire tagging chinook salmon stocked into Lake Oahe were to determine effects of stocking date, size and imprinting attempts on initial survival, growth, maturation patterns, and homing ability; to determine optimum stocking strategies. Due to the complexity of the experimental design of this project, specific objectives, treatments and results will be presented for each brood year separately. The discussion section of this report will attempt to synthesize results from individual brood year experiments.

<u>1986 Brood Year</u>

Objectives of CWT chinook salmon stockings of 1986-brood-year fish were to determine effects of artificial imprinting and size-and-date at stocking on homing ability and initial survival. Specifics of CWT stocking groups for the 1986-brood year are presented in Table 3.

Table 3. Chinook salmon coded-wire-tag-group statistics for tagging groups from the 1986-brood year. Treatment effects tested for the 1986-brood year included morpholine imprinting and size-and-date at stocking.

Treatment	Number stocked	Kilograms stocked	Average size at stocking (g)	Stocking location	Stocking date
21-d morpholine imprint at Blue Dog and 14-d morpholine imprint at Whitlocks station	29,602	192.4	6.5	Whitlocks Bay	4/15/87
Held 14-d at Whitlocks station	29,910	194.4	6.5	Whitlocks Bay	4/15/87
Held 14-d at Whitlocks station	19,876	284.2	14.3	Whitlocks Bay	5/18/87
21-d morpholine imprint at Blue Dog and 14-d morpholine imprint at Whitlocks station	20,188	288.7	14.3	Whitlocks Bay	5/18/87

As with most comparisons of CWT groups involving differences in size at stocking, both size and date at stocking were inter-related with chinook salmon averaging 14.3 g at stocking, being stocked approximately one month after fish averaging 6.5 g. All CWT-treatment groups from the 1986-brood year were stocked as spring-age-0 fish.

The total numbers of CWT chinook salmon returning to the spawning station and fishery were significantly higher ($P<0.05$) for non-morpholine-treated 6.5-g chinook salmon, than for morpholine-treated chinook salmon of the same size at stocking (Table 4). Morpholine-treated fish suffered higher initial mortality before recruitment to the fishery than non-treated fish, as return ratios of treated fish to non-treated fish were similar for the fishery and spawning station (1:1.72 and 1:1.47, respectively). Morpholine-treated 14.3-g chinook salmon did not experience the differentially higher mortality documented for morpholine-treated 6.5-g fish. No difference between treated and non-treated total return numbers of 14.3-g fish in the fishery was observed (Table 4). However, morpholine treating failed to result in higher return rates of treated fish to the spawning station.

Table 4. Numbers of chinook salmon from each treatment group from the 1986 brood year that returned to the Whitlocks Bay spawning station and to the fishery by year, age and sex. For each age category, the younger age corresponds to fish in the fishery and the older age corresponds to fish at the spawning station.

Treatment	Return location	Sex	Number returned by year and age						Total return
			1987 0-1	1988 1-2	1989 2-3	1990 3-4	1991 4-5	1992 5-6	
6.5-g, 21-d morpholine	station	M		5	17	10	2		34
imprint at Blue Dog	station	F			7	9	1		17
and 14-d morpholine	station	T		5	24	19	3		51
at Whitlocks station	fishery			32	19	12	5		68
6.5 g, held 14-d at	station	M		15	28	8	1		52
Whitlocks station	station	F			9	14	1		24
	station	T		15	37	22	2		76
	fishery		1	51	38	27	1		118
14.3-g, held 14-d at	station	M		25	15	7	1		48
Whitlocks station	station	F			18	18	3		39
	station	T		25	33	25	4		92
	fishery		4	85	54	28	5	1	177
14.3-g, 21-d morpholine	station	M		20	32	1	1		54
imprint at Blue Dog	station	F			13	17	3	1	34
and 14-d morpholine	station	T		20	45	18	4	1	88
at Whitlocks station	fishery		2	74	39	28	2		145

Because morpholine treatment of 6.5-g chinook salmon appeared related to higher mortality rates before recruitment to the fishery, effects of size-and-date at stocking will only be discussed for non-treated groups. Non-treated 14.3-g chinook salmon had total return numbers greater ($P<0.05$) than 6.5-g chinook salmon to the fishery and spawning station, when total number returned was weighted by number stocked. However, when total number returned was weighted by kilograms stocked, no difference in total numbers returned to the fishery or spawning station was observed. ($P>0.05$ in both cases; Table 4).

Significant differences in maturation patterns were noted between males of all CWT groups ($P<0.01$) of the 1986-brood year but not between females (Table 5). No differences in pattern of contribution to the fishery were noted between any of the CWT groups from the 1986-brood year. All CWT groups from the 1986-brood year made their greatest contribution to the fishery during their second year of life (age 1-2). The highest percentage of chinook salmon males (for all 1986-brood-year-CWT groups) maturing in a year occurred for age-3 fish (1989), while the highest percentage of females matured at age 4 (1990). Males generally begin maturing a year sooner than females. Mature fish of age 4 and age 5, of both sexes, were present in all CWT groups from the 1986-brood year.

Table 5. Percent of total return of chinook salmon from each treatment group from the 1986-brood year that returned to the Whitlocks Bay spawning station and to the fishery by year, age and sex. For each age category, the younger age corresponds to fish in the fishery and the older age corresponds to fish at the spawning station.

Treatment	Return location	Sex	N	Percent total return by year and age					
				1987 0-1	1988 1-2	1989 2-3	1990 3-4	1991 4-5	1992 5-6
6.5-g, 21-d morpholine	station	M	34		14.7	50.0	29.4	5.9	
imprint at Blue Dog	station	F	17		0.0	41.2	52.9	5.9	
and 14-d morpholine	station	T	51		9.8	47.1	37.3	5.9	
at Whitlocks station	fishery		68		47.1	27.9	17.6	7.4	
6.5 g, held 14-d at	station	M	52		28.8	53.8	15.4	1.9	
Whitlocks station	station	F	24		0.0	37.5	58.3	4.2	
	station	T	76		19.7	48.7	28.9	2.6	
	fishery		118	0.8	43.2	32.2	22.9	0.8	
14.3-g, held 14-d at	station	M	48		52.1	31.3	14.6	2.1	
Whitlocks station	station	F	39		0.0	46.2	46.2	7.7	
	station	T	92		28.7	37.9	28.7	4.6	
	fishery		177	2.3	48.0	30.5	15.8	2.8	0.6
14.3-g, 21-d morpholine	station	M	54		37.0	59.3	1.9	1.9	
imprint at Blue Dog	station	F	34		0.0	38.2	50.0	8.8	2.9
and 14-d morpholine	station	T	88		22.7	51.1	20.5	4.5	1.1
at Whitlocks station	fishery		145	1.4	51.0	26.9	19.3	1.4	

Again, because of differences in mortality rates for morpholine-treated fish, mean weight of salmon returning to the spawning station was only compared between non-morpholine-treated groups. All comparisons were made between fish of the same sex and age. In general, size at stocking seemed to have little impact on size at maturity as only age-4 (maturing in 1990) females from the group stocked at an average size of 14.3 g were significantly larger (P=0.03) than chinook salmon from the non-treated group stocked at an average size of 6.5 g. (Table 6). Chinook salmon from the 1986-brood year did not generally reach 3 kg in weight until age 4 or age 5 (Table 6).

Table 6. Mean weight of chinook salmon from each treatment group from the 1986-brood year that returned to the Whitlocks Bay spawning station by year, age and sex.

Treatment		Mean weight (kg) at return by year, age and sex											
		1987		1988		1989		1990		1991		1992	
		1		2		3		4		5		6	
		M	F	M	F	M	F	M	F	M	F	M	F
6.5-g, 21-d morpholine	N			5		17	7	10	9	2	1		
imprint at Blue Dog	Mean			1.4		1.8	1.8	2.2	2.0	1.2	3.1		
and 14-d morpholine	SE			0.2		0.1	0.1	0.1	0.2	0.3	----		
at Whitlocks station													
6.5 g, held 14-d at	N			15		28	9	8	14	1	1		
Whitlocks station	Mean			1.1		1.8	1.4	1.7	1.9	1.1	2.9		
	SE			0.1		0.1	0.1	0.2	0.1	----	----		
14.3-g, held 14-d at	N			25		15	18	7	18	1	3		
Whitlocks station	Mean			1.3		1.8	1.7	2.1	2.2	2.3	3.7		
	SE			0.0		0.1	0.1	0.2	0.2	----	0.2		
14.3-g, 21-d morpholine	N			20		32	13	1	17	1	3		1
imprint at Blue Dog	Mean			1.2		1.7	1.6	1.2	2.0	3.3	3.4		3.3
and 14-d morpholine	SE			0.1		0.1	0.1	----	0.2	----	0.6		----
at Whitlocks station													

1987 Brood Year

Objectives of the CWT chinook salmon stockings for the 1987-brood year were to evaluate the performance of two combinations of size-and-date at stocking and to compare the performance of chinook salmon stocked as spring-age-0 fish with that of salmon stocked as spring age-1 fish. Information on CWT treatment groups used in these evaluations appears in Table 7. The CWT group stocked at the West Shore boat ramp will not be used in comparisons of returns to the spawning station or fishery among CWT groups, as it is believed that the majority of the fish from this stocking followed their natural instincts and migrated downstream, through Oahe Dam during their first summer of life. Forty-six chinook salmon from this group were recaptured, compared to 95 from the group stocked 1 day later at Whitlocks Bay.

The number of CWT chinook salmon from the group averaging 15.1 g at stocking (spring age 0), that returned to the spawning station was significantly greater ($P<0.05$) than the number of chinook salmon from the group averaging 7.1 g at stocking (spring age 0), when returns were weighted by numbers stocked (Table 8). When total number returned was weighted by numbers of each group stocked, fish stocked at 15.1 g returned at a higher rate to the fishery ($P<0.05$). However, when weighted by kilograms stocked, no difference in total returns to the spawning station or the fishery were observed (Table 8).

Table 7. Chinook salmon coded-wire-tag-group statistics for tagging groups from the 1987-brood year. Treatment effects tested for the 1987-brood year included size-and-date at stocking. Chinook salmon stocked during May 1990 and April of 1991 were approximately 6- and 17-months old when stocked, respectively.

Treatment	Number stocked	Kilograms stocked	Average size at stocking (g)	Stocking location	Stocking date
Held at Whitlocks station 10-d before release	64,508	458.0	7.1	Whitlocks Bay	5/12/88
Held at Whitlocks station 14-d before release	53,815	812.6	15.1	Whitlocks Bay	5/31/88
Directly stocked	6,235	859.4	137.5	West Shore, Oahe Dam	4/12/89
Held 4 d at Whitlocks station before release	6,250	859.4	137.5	Whitlocks Bay	4/13/89

Table 8. Numbers of chinook salmon from each treatment group from the 1987-brood year that returned to the Whitlocks Bay spawning station and to the fishery by year, age and sex. For each age category, the younger age corresponds to fish in the fishery and the older age corresponds to fish at the spawning station.

Treatment	Return location	Sex	Number returned by year and age						Total return
			1988 0-1	1989 1-2	1990 2-3	1991 3-4	1992 4-5	1993 5-6	
7.1-g, held at Whitlocks station for 10-d before release	station	M		3	25	6		1	35
	station	F			5	8		1	14
	station	T		3	30	14		2	49
	fishery		2	18	39	26	5		90
15.1-g, held at Whitlocks station for 14-d before release	station	M		7	55	10	1		73
	station	F			15	30	7		52
	station	T		7	70	40	8		125
	fishery		4	37	81	52	9		183
137.5-g, directly stocked at West Shore, Lake Oahe	station	M							
	station	F					2		2
	station	T					2		2
	fishery			14	15	7	8		44
137.5-g held at Whitlocks station for 4-d before release	station	M		61					61
	station	F				5	1		6
	station	T		61		5	1		67
	fishery			5	7	10	6		28

Chinook salmon averaging 137.5 g at stocking (spring age 1) returned better (P<0.05) to the spawning station than those averaging 7.1 g at stocking (spring age 0), when returns were weighted by number stocked. When weighted by kilograms stocked, no difference in numbers returned was evident (Table 8). However, 137.5-g chinook salmon were better represented in the fishery than 7.1 g fish when returns were weighted by both number and kilograms stocked (Table 8). Chinook salmon averaging 137.5 g (spring age 1) at stocking returned better (P<0.05) to the spawning station and the fishery, than 15.1-g fish (spring age-0), when returns were weighted by both number and kilograms stocked (Table 7).

No differences in maturation patterns were detected between 1987-brood-year CWT chinook salmon stocked at an average size of 7.1 g or 15.1 g as spring-age-0 fish, of either sex, or in patterns of return to the fishery (P>0.05 in all cases; Table 9). Spring-age-0-CWT groups did have patterns in maturation and return to the fishery that were different (P<0.01 in all cases) than those observed for the spring age-1 CWT group stocked at Whitlocks Bay (Table 9).

The peak in percent maturation of males stocked as spring age-0 fish occurred at age 3 (matured in 1990) at 71.4% and 75.3% for CWT groups stocked at average sizes of 7.1 g and 15.1 g, respectively (Table 9). Raising male chinook salmon to spring age 1 before stocking, resulted in 100% maturation as jacks, only seven months after stocking (Table 9). These did not make a noticeable contribution to the fishery in 1989 (as age 1 fish) and then matured and were lost from the population before they ever contributed to the angler harvest. Raising male chinook salmon to spring age-1 prior to release increased precocialness.

The peak in percent maturation of females stocked as age-0 fish occurred at age 4 (matured in 1991) at 57.1% and 57.7% for CWT groups stocked at average sizes of 7.1 g and 15.1 g, respectively (Table 7). Substantial proportions (35.7% and 28.8%) of total female returns from these groups matured at age 3. A small percentage (7.1%) of the females from the group stocked at an average size of 7.1 g matured at age 6 while 13.5% of those stocked at an average size of 15.1 g matured at age 5 (Table 9). Noticeable differences (P<0.01in both cases) existed between the maturation patterns of spring-age-0-stocked chinook salmon and those stocked as spring age-1 fish (Table 9). Approximately one third of spring-age-0-stocked females matured at age 3, while no females stocked at spring age 1 matured at this age. The majority (83%) of female stocked at spring age 1 matured at age 4 and 17% matured at age 5. Raising chinook salmon to spring age 1 prior to release resulted in an increase in the percent of females maturing at age 4, and in general, a later onset of maturity.

Table 9. Percent of total return of chinook salmon from each treatment group from the 1987-brood year that returned to the Whitlocks Bay spawning station and to the fishery by year, age and sex. For each age category, the younger age corresponds to fish in the fishery and the older age corresponds to fish at the spawning station.

Treatment	Return location	Sex	N	Percent total returns by year and age					
				1988 0-1	1989 1-2	1990 2-3	1991 3-4	1992 4-5	1993 5-6
7.1-g, held at Whitlocks station for 10-d before release	station	M	35		8.6	71.4	17.1		2.9
	station	F	14			35.7	57.1		7.1
	station	T	49		6.1	61.2	28.6		4.1
	fishery		90	2.2	20.0	43.3	28.9	5.6	
15.1-g, held at Whitlocks station for 14-d before release	station	M	73		9.6	75.3	13.7	1.4	
	station	F	52			28.8	57.7	13.5	
	station	T	125		5.6	56.0	32.0	6.4	
	fishery		183	2.2	20.2	44.3	28.4	4.9	
137.5-g, directly stocked at West Shore, Lake Oahe	station	M							
	station	F	2					100	
	station	T	2					100	
	fishery		44		31.8	34.1	15.9	18.2	
137.5-g held at Whitlocks station for 4-d before release	station	M	61		100				
	station	F	6				83.3	17	
	station	T	67		91.0		7.5	1.5	
	fishery		28		17.9	25.0	35.7	21.4	

No difference (P=0.40) in mean weight at age of return to the spawning station was noted among sexes for CWT groups from the 1987 brood year. However, significant differences did exist among stocking groups, with females from the spring age-1 stocking being smaller at age 4 and age 5 ($P \leq 0.01$ in all cases) than females stocked at spring age 0 (Table 10). Males from the spring-age-1 stocking at Whitlocks Bay were not smaller than those from spring-age-0 stockings, as mature age-2 fish ($P > 0.05$ in both cases). However, the precocial nature of these fish and the short time period they were in the reservoir before maturing, resulted in little contribution to the fishery before they matured.

Table 10. Mean weight of chinook salmon from each treatment group from the 1987 brood year that returned to the Whitlocks Bay spawning station by year, age and sex.

Treatment		Mean weight (kg) at return by year, age and sex											
		1988		1989		1990		1991		1992		1993	
		1		2		3		4		5		6	
		M	F	M	F	M	F	M	F	M	F	M	F
7.1-g, held at Whitlocks station for 10-d before release	N			3		25	5	6	8			1	1
	Mean			1.0		2.0	1.8	3.7	3.9			3.9	6.4
	SE			0.1		0.1	0.1	0.1	0.2			---	---
15.1-g, held at Whitlocks station for 14-d before release	N			7		55	15	10	30	1	7		
	Mean			1.0		2.1	1.7	3.4	3.4	4.2	3.3		
	SE			0.1		0.1	0.1	0.2	0.1	---	0.4		
137.5-g, directly stocked at West Shore, Lake Oahe	N										1		
	Mean										2.2		
	SE										0.2		
137.5-g held at Whitlocks station for 4-d before release	N			61					5		1		
	Mean			0.6					2.7		2.0		
	SE			0.0					0.3		---		

1988 Brood Year

Objectives of CWT chinook salmon stockings of 1988-brood-year fish were to evaluate effects of size-and-date at stocking and release practice (holding at spawning station vs. direct release) on survival, growth, maturation and homing ability. Specifics of CWT-stocking groups for the 1998-brood year appear in Table 11.

Table 11. Chinook salmon coded-wire-tag-group statistics for tagging groups from the 1988-brood year. Treatment effects tested for the 1988-brood year included holding fish at the Whitlocks Bay spawning station prior to release vs. directly stocking fish into Whitlocks Bay size-and-date at stocking.

Treatment	Number stocked	Kilograms stocked	Average size at stocking (g)	Stocking location	Stocking date
Held at Whitlocks station for 10-d before stocking	28,999	301.6	10.4	Whitlocks Bay	5/25/89
Directly stocked	30,164	398.2	13.2	Whitlocks Bay	6/5/89

Significantly more (P<0.05) chinook salmon from the CWT group averaging 13.2 g when directly stocked into Whitlocks Bay, returned to the spawning station, than did salmon from the group averaging 10.4 g that were held at the station, when total returns were weighted by number of fish stocked (Table 12). However, when total numbers returning were weighted by kilograms stocked, no difference (P>0.05) in total number returning to the spawning station existed between groups (Table 12). The total number of chinook salmon from both CWT groups from the 1988-brood year that returned to the fishery were similar (P>0.05). Chinook salmon from the 10.4-g CWT group were stressed at stocking because of a power outage at the spawning station. These fish were released when the power outage was discovered but had already become stressed due to low oxygen levels in the raceways. No difference was observed in total return rates in the fishery between the group held at the station and those directly stocked into Whitlocks Bay. The greater total return of chinook salmon from the CWT group directly stocked into Whitlocks Bay to the spawning station suggests holding fish at the spawning station did not improve their ability to home back to the station.

Table 12. Numbers of chinook salmon from each treatment group from the 1988-brood year that returned to the Whitlocks Bay spawning station and to the fishery by year, age and sex. For each age category, the younger age corresponds to fish in the fishery and the older age corresponds to fish at the spawning station.

Treatment	Return location	Sex	Number returned by year and age						Total return
			1989 0-1	1990 1-2	1991 2-3	1992 3-4	1993 4-5	1994 5-6	
10.4-g, held at Whitlocks	station	M	3	3	52	3			61
station for 10-d before	station	F			13	19			32
stocking	station	T	3	3	65	22			93
	fishery		1	9	26	29	1		66
13.2-g, directly stocked	station	M	5	7	72	10			94
	station	F			12	40			52
	station	T	5	7	84	50			146
	fishery		4	11	34	34			83

No difference existed in patterns of maturation of males, (P>0.05) between chinook-salmon-CWT groups from the 1988-brood year (Table 13); however, a higher percentage of females from the 10.4-g CWT group matured at age 3 (40.6%; Table 13). There was also no difference in patterns of return in the fishery between CWT groups from the 1988-brood year. The majority of males from both CWT groups matured at age 3 (85.2% and 76.6%) and a low incidence of jacks characterized this year class. However, a small percentage (4-9-5.3%) of the males of these CWT groups also matured as age-1 fish. Of special note, only one fish from this brood year returned to the spawning station at age 5 and no age-6 fish from this year class were observed. Chinook salmon from the 1988-brood year made their greatest contribution to the angler harvest as age-3 and age-4 fish, with similar percent contributions for each age group (Table 13).

Table 13. Percent of total return of chinook salmon from each treatment group from the 1988-brood year that returned to the Whitlocks Bay spawning station and to the fishery by year, age and sex. For each age category, the younger age corresponds to fish in the fishery and the older age corresponds to fish at the spawning station.

Treatment	Return location	Sex	N	Percent total returns by year and age					
				1989 0-1	1990 1-2	1991 2-3	1992 3-4	1993 4-5	1994 5-6
10.4-g, held at Whitlocks station for 10-d before stocking	station	M	61	4.9	4.9	85.2	4.9		
	station	F	32			40.6	59.4		
	station	T	93	3.2	3.2	69.9	23.7		
	fishery		66	1.5	13.6	39.4	43.9	1.5	
13.2-g, directly stocked	station	M	94	5.3	7.4	76.6	10.6		
	station	F	52			23.1	76.9		
	station	T	146	3.4	4.8	57.5	34.2		
	fishery		83	4.8	13.3	41.0	41.0		

No difference (P=0.40) in mean weight at age of return to the spawning station was noted between sexes for CWT groups from the 1988-brood year (Table 14). Growth rates were relatively poor during 1989 and 1990, then increase substantially in 1991.

Table 14. Mean weight of chinook salmon from each treatment group from the 1988-brood year that returned to the Whitlocks Bay spawning station by year, age and sex.

Treatment		Mean weight (kg) at return by year, age and sex											
		1989 1		1990 2		1991 3		1992 4		1993 5		1994 6	
		M	F	M	F	M	F	M	F	M	F	M	F
10.4-g, held at Whitlocks	N	3		3		52	13	3	19				
station for 10-d before	Mean	0.3		1.0		3.1	3.3	4.3	3.7				
stocking	SE	0.1		0.1		0.1	0.1	0.1	0.1				
13.2-g, directly stocked	N	5		7		72	12	10	40				
	Mean	0.1		1.0		3.2	3.3	3.7	3.8				
	SE	0.0		0.2		0.1	0.1	0.4	0.1				

1989 Brood Year

Objectives of CWT chinook salmon stockings of 1989-brood-year fish were to evaluate the effects of three different size-and-date-at-stocking combinations on initial survival, patterns in maturity and growth. Chinook-salmon-CWT groups from this brood year were stocked as spring-age-0, fall-age-0, and spring-age-1 fish (Table 15). The objective of rearing chinook salmon for longer periods of time prior to stocking was to increase initial survival by stocking fish at a larger size. If initial survival was increased, the same contribution to the population could be made by stocking fewer, larger fish. Even though the spring-age-0-and fall-age-0-CWT groups were held at the spawning station prior to stocking, effects of holding fish at the station on homing ability were not addressed as no direct-stocked fish of the same size were stocked for comparison.

Table 15. Chinook salmon coded-wire-tag-group statistics for tagging groups from the 1989-brood year. Treatment effects tested for the 1989-brood year included holding fish at the Whitlocks Bay spawning station prior to release vs. directly stocking fish into Whitlocks Bay size-and-date at stocking. Chinook salmon stocked during June 1990, November 1990 and April 1991 were approximately 7-, 11- and 17-months old when stocked, respectively.

Treatment	Number stocked	Kilograms stocked	Average size at stocking (g)	Stocking location	Stocking date
Held at Whitlocks station 25-d before stocking	29,019	249.6	8.6	Whitlocks Bay	6/8/90
Held at Whitlocks station 15-d before stocking	7,704	436.8	56.7	Whitlocks Bay	11/1/90
Directly stocked	9,232	1443.9	156.4	Whitlocks Bay	4/24/91

Chinook salmon stocked as fall-age-0 fish averaging 56.7 g returned better ($P<0.05$) to the spawning station and fishery than 8.6-g, spring-age-0 fish, when total returns were weighted by number stocked (Table 16). However, when weighted by kilograms stocked, spring-age-0 fish returned to both the spawning station and fishery in higher numbers ($P<0.05$) than did fall-age-0 fish.

Chinook salmon stocked as spring-age-1 fish averaging 156.4 g returned better ($P<0.05$) to the spawning station and fishery than those stocked as 8.6-g spring-age-0 fish, when total returns were weighted by number stocked (Table 16). However, when weighted by kilograms stocked, fish stocked at spring age 0 returned to both the spawning station and fishery in higher numbers ($P<0.05$) than did fish stocked at spring- age-1.

Chinook salmon stocked as 156.4-g, spring-age-1 fish returned better ($P<0.05$) to the spawning station and fishery than 56.7-g fall-age-0 fish, when total returns were weighted by number stocked (Table 16). When total numbers returned were weighted by kilograms stocked, no difference in total returns to the spawning station was observed, while the fall-age-0 stocking resulted in a higher total return to the fishery than the spring-age-1 stocking (Table 16).

In summary, on a per-fish-stocked basis, spring-age-1-stocked fish returned at the highest rate followed by fall-age-0 and spring age-0 fish. However, on a per-kilogram-stocked basis, spring-age-0 fish (8.6 g average) returned at higher rates than their fall-age-0 and spring-age-1 counterparts.

Table 16. Numbers of chinook salmon from each treatment group from the 1989-brood year that returned to the Whitlocks Bay spawning station and to the fishery by year, age and sex. For each age category, the younger age corresponds to fish in the fishery and the older age corresponds to fish at the spawning station.

Treatment	Return location	Sex	Number returned by year and age						Total return
			1990 0-1	1991 1-2	1992 2-3	1993 3-4	1994 4-5	1995 5-6	
8.6-g, held at Whitlocks	station	M	1	15	29	1			46
station 25-d before	station	F			43	17			60
stocking	station	T	1	15	72	18			106
	fishery			16	85	13			114
56.7-g, held at Whitlocks	station	M		13	22	6			41
station 15-d before	station	F		1	6	60			67
stocking	station	T		14	28	66			108
	fishery			1	54	38			93
156.4-g, directly	station	M		293	3	2			298
stocked in Whitlocks	station	F			22	61			83
Bay	station	T		293	25	63			381
	fishery			24	101	52			177

Patterns in maturation of males differed greatly ($P<0.01$ in all cases) among the three 1989-brood-year-CWT groups (Table 17). The spring-age-0 and fall-age-0-CWT-stocking groups had similar percentages of males maturing at age 2, at 32.6% and 31.7%, respectively. As observed for the spring-age-1-CWT stocking group from the 1987 brood year, nearly all males (98.3%) from the spring-age-1 CWT group from the 1989-brood year matured at age 2 and were lost from the population approximately 7 months after stocking (Table 17). The peak in percent maturation of males for the spring-age-0 and fall-age-0-CWT-stocking groups occurred at age 3.

Patterns in maturation of females also differed ($P<0.01$ in all cases) significantly between CWT-stocking groups from the 1989-brood year. Chinook salmon reared to advanced sizes and stocked as fall-age-0 or spring-age-1 fish had peaks in percentage of females maturing at age 4, while the peak in maturation for the spring-age-0-CWT group occurred at age 3 (Table 17). The patterns in maturation of females are almost opposite for spring-age-0-stocked fish and those stocked as fall-age-0 and spring-age-1 fish (Table 17).

Patterns in return to the fishery of chinook salmon differed greatly ($P<0.01$ in all cases) among 1989-brood-year-CWT groups (Table 17). The highest percentage of total return to the fishery for all three CWT groups occurred during the summer of 1993 when fish were age 2+. Due to the higher percentages of females from the fall-age-0 and spring-age-1-CWT-stocking groups maturing at age 4, these groups contributed more to the fishery as age-3+ fish than did females from the spring-age-0-CWT group (Table 17).

The 1989-brood year stocking was the first stocking from which age-4+ fish in the population in the summer and age-5 fish at the station were absent (Table 17), indicating maturation at younger ages and/or higher rates of mortality during the groups' life span.

Table 17. Percent of total return of chinook salmon from each treatment group from the 1989-brood year that returned to the Whitlocks Bay spawning station and to the fishery by year, age and sex. For each age category, the younger age corresponds to fish in the fishery and the older age corresponds to fish at the spawning station.

Treatment	Return location	Sex	N	Percent total returns by year and age					
				1990 0-1	1991 1-2	1992 2-3	1993 3-4	1994 4-5	1995 5-6
8.6-g, held at Whitlocks	station	M	46	2.2	32.6	63.0	2.2		
station 25-d before	station	F	60			71.7	28.3		
stocking	station	T	106	0.9	14.2	67.9	17.0		
	fishery		114		14.0	74.6	11.4		
56.7-g, held at Whitlocks	station	M	41		31.7	53.7	14.6		
station 15-d before	station	F	67		1.5	9.0	89.6		
stocking	station	T	108		13.0	25.9	61.1		
	fishery		93		1.1	58.1	40.9		
156.4-g, directly	station	M	298		98.3	1.0	0.7		
stocked in Whitlocks	station	F	83			26.5	73.5		
Bay	station	T	381		76.9	6.6	16.5		
	fishery		177		13.6	57.1	29.4		

Raising chinook salmon to fall age 0 or spring age 1 resulted in fish from these stocking groups being smaller in size when stocked than their wild-feeding, brood-year counterparts stocked as spring-age-0 fish (Table 18). This in turn, caused fish from the fall-age-0 and spring-age-1 stockings to be smaller on average, at age of maturity than were fish from the spring-age-0-CWT group. Weights of males from the 1989-brood year, stocked at spring-age-0 were significantly greater at maturity at age 2 and age 3 than males from the fall-age-0 and spring-age-1 stockings ($P<0.01$ in all cases). No differences in mean weight at maturity at age 4 were detected among the three CWT groups from the 1989 brood year, possibly due to small sample size. No difference in mean weight at maturity between males from the spring-age-0- and fall-age-1-CWT groups was evident at any age (Table 18).

Among females of the three 1989-brood-year-CWT groups, fish from the spring-age-0-CWT group were significantly larger at maturation at age 3 than fish from the fall-age-0- and spring-age-1-CWT groups (P=0.02 and P<0.01, respectively). However, for fish maturing at age 4, there was no difference in mean weight between females from the spring-age-0- and fall-age-0-CWT groups and mean weight at maturity for spring-age-1-stocked fish was significantly lower than for spring-age-0 and fall-age-0-stocked fish (Table 18).

Table 18. Mean weight of chinook salmon from each treatment group from the 1989-brood year that returned to the Whitlocks Bay spawning station by year, age and sex.

Treatment		Mean weight (kg) at return by year, age and sex											
		1990		1991		1992		1993		1994		1995	
		1		2		3		4		5		6	
		M	F	M	F	M	F	M	F	M	F	M	F
8.6-g, held at Whitlocks station 25-d before stocking	N	1		15		29	43	1	17				
	Mean	0.1		1.6		3.9	3.3	6.2	4.9				
	SE	---		0.1		0.1	0.1	---	0.3				
56.7-g, held at Whitlocks station 15-d before stocking	N			13	1	22	6	6	60				
	Mean			0.8	2.9	3.4	2.6	5.3	4.9				
	SE			0.1	---	0.1	0.2	0.6	0.1				
156.4-g, directly stocked in Whitlocks Bay	N			293		3	22	2	61				
	Mean			0.8		2.7	2.6	4.4	4.5				
	SE			0.0		0.1	0.1	0.1	0.2				

1990 Brood Year

The objective of CWT chinook salmon stockings of 1990-brood-year fish was to evaluate the effect of holding spring-age-0 chinook salmon at the spawning station prior to release on their ability to home back to the spawning station at maturity. Chinook salmon held at the station were stocked at approximately the same time and at the same size as another CWT group stocked directly into Whitlocks Bay. Specifics of the 1990-brood-year-CWT groups are provided in Table 19.

Table 19. Chinook salmon coded-wire-tag-group statistics for tagging groups from the 1990-brood year. Treatment effects tested for the 1990-brood year included holding fish at the Whitlocks Bay spawning station prior to release vs. directly stocking fish into Whitlocks Bay.

Treatment	Number stocked	Kilograms stocked	Average size at stocking (g)	Stocking location	Stocking date
Held 14-d at Whitlocks station prior to stocking	17,850	180.3	10.1	Whitlocks Bay	5/15/91
Directly stocked into Lake Oahe	19,242	188.6	9.8	Whitlocks Bay	5/16/91

The total number of chinook salmon from each CWT group for the 1990-brood year, returning to the spawning station, was similar ($P>0.05$). However, chinook salmon from the CWT group held at the spawning station prior to release had a greater total return to the fishery ($P<0.05$) than those directly stocked into Lake Oahe at Whitlocks Bay (Table 20). A greater total return to the fishery of CWT fish held at the station, suggests higher initial survival of this group than the group directly stocked (Table 20). Forty-one percent more fish of the CWT group held at the station were returned to the fishery, when returns were weighted by number stocked, than from the CWT group directly stocked. The number returning to the station should then have been 41% greater for the CWT group held at the station prior to stocking if no difference in homing ability existed. The 1:1 ratio of total number returning to the station, of fish held at the station to those directly stocked, indicates a better return of direct-stocked fish to the station than those held at the station prior to stocking.. Holding chinook salmon at the spawning station prior to release did not improve homing ability.

Table 20. Numbers of chinook salmon from each treatment group from the 1990-brood year that returned to the Whitlocks Bay spawning station and to the fishery by year, age and sex. For each age category, the younger age corresponds to fish in the fishery and the older age corresponds to fish at the spawning station.

Treatment	Return location	Sex	Number returned by year and age						Total return
			1991 0-1	1992 1-2	1993 2-3	1994 3-4	1995 4-5	1996 5-6	
10.1-g, held 14-d at Whitlocks station prior stocking	station	M	3	19	37	2			61
	station	F		3	32	10			45
	station	T	3	22	69	12			106
	Fishery		2	25	73	7			107
9.8-g, directly stocked into Lake Oahe	station	M	6	21	33	2			62
	station	F			48	4			52
	station	T	6	21	81	6			114
	Fishery			32	49	1			82

Patterns in maturation of male chinook salmon from the two 1990-brood-year-CWT groups were very similar with a small percentage of fish maturing at age 1 and the peak in percent maturation occurring at age 3 (Table 21). The percentage of males, from these CWT groups, maturing as jacks was also similar at 31.1% and 33.9%.

Maturation patterns were similar for females from the 1990-brood-year-CWT groups (Table 21). For both CWT groups, the peak in percent female maturation occurred at age 3. A larger percentage of the CWT group held at the station prior to release matured at age 4 and three age-2 females returned to the station from this group. Beginning with the 1989-brood year, the peak in female percent maturation for spring-age-0-stocked fish, occurred at age 3 (matured in 1992), rather than at age 4, as in previous years.

Differences in return patterns to the fishery also existed between CWT groups from the 1990-brood year (P<0.03; Table 21). A greater percentage of the total return to the fishery of the CWT group directly stocked into Lake Oahe returned to the fishery at age-1+ in the summer of 1992.

Table 21. Percent of total return of chinook salmon from each treatment group from the 1990-brood year that returned to the Whitlocks Bay spawning station and to the fishery by year, age and sex. For each age category, the younger age corresponds to fish in the fishery and the older age corresponds to fish at the spawning station.

Treatment	Return location	Sex	N	Percent total returns by year and age					
				1991 0-1	1992 1-2	1993 2-3	1994 3-4	1995 4-5	1996 5-6
10.1-g, held 14-d at Whitlocks station prior stocking	station	M	61	4.9	31.1	60.7	3.3		
	station	F	45		6.7	71.1	22.2		
	station	T	106	2.8	20.8	65.1	11.3		
	Fishery		107	1.9	23.4	68.2	6.5		
9.8-g, directly stocked into Lake Oahe	station	M	62	9.7	33.9	53.2	3.2		
	station	F	52			92.3	7.7		
	station	T	114	5.3	18.4	71.1	5.3		
	Fishery		82		39.0	59.8	1.2		

Growth of chinook salmon from the 1990 brood year was fast when compared with other CWT-fish-brood years (1986-1992), with mean weights of males maturing at age 2 of 1.8 kg and 1.9 kg, and mean weights of females maturing at age 3 of 3.9 kg and 4.0 kg, for the two 1990-brood-year-CWT groups (Table 22). No differences in mean weight at age at maturity, by sex, existed between the two CWT groups from the 1990-brood year.

Table 22. Mean weight of chinook salmon from each treatment group from the 1990-brood year that returned to the Whitlocks Bay spawning station by year, age and sex.

Treatment		Mean weight (kg) at return by year, age and sex											
		1991		1992		1993		1994		1995		1996	
		1		2		3		4		5		6	
		M	F	M	F	M	F	M	F	M	F	M	F
10.1-g, held 14-d at Whitlocks station prior to stocking	N	3		19	3	37	32	2	10				
	Mean	0.3		1.9	2.0	5.0	4.0	3.0	3.5				
	SE	0.0		0.1	0.2	0.1	0.1	0.2	0.2				
9.8-g, directly stocked into Lake Oahe	N	6		21		33	48	2	4				
	Mean	0.7		1.8		4.5	3.9	4.4	4.0				
	SE	0.4		0.1		0.2	0.1	1.3	0.3				

1991 Brood Year

The objective of CWT chinook salmon stockings of 1991-brood-year fish was to compare the performance of "runts", encountered during CWT implantation operations at McNenny State Fish Hatchery with fish in normal condition when marked. Specifics of CWT groups for the 1991 brood year appear in Table 23. Unfortunately, too few "runts" were tagged to provide an adequate number of tag returns to allow any meaningful data interpretation. If the numbers of tags returned at the station or in the fishery from the "runts" CWT group did not accurately reflect the performance of this group, even to the smallest degree, this inaccuracy would be magnified 11.5 times or 23.5 times by weighting numbers returned to compensate for differences in number and kilograms of fish stocked, respectively. The standard spring-age-0 stocking was assessed for patterns in maturation, return to the fishery and growth, for comparisons with trend data for the 1986-1992 brood years.

Table 23. Chinook salmon coded-wire-tag-group statistics for tagging groups from the 1991-brood year. Treatment effects tested for the 1991-brood year included comparing chinook salmon at a standard stocking size with "runts".

Treatment	Number stocked	Kilograms stocked	Average size at stocking (g)	Stocking location	Stocking date
Direct stocking	30,193	465.0	15.4	Whitlocks Bay	5/27/92
direct stocking of "runts"	2,623	19.7	7.5	Whitlocks Bay	5/27/92

Table 24 reinforces the point that too few tag returns were turned in from the "runts" CWT group to allow meaningful interpretation of the data. Numbers of chinook salmon from the standard spring-age-0 stocking of 1991-brood-year fish were higher than for most other brood years (Table 24).

For the 1991-brood-year-CWT groups, the peak in return percentage of males to the spawning station occurred at age 3. The percent of males maturing as jacks was the highest observed for any spring-age-0-stocked CWT group from the 1986-1992-brood years (Table 25). The peak in percentage of females from the 1991 brood year returning to the spawning station occurred at age 3, at 89.9%. This value follows a trend where percent of females maturing at age 3 increased steadily beginning with the 1989 brood year, which reached age 3 in the fall of 1992. As a larger percentage of fish of both sexes have matured at the earliest age at which maturation is generally reached (age 2 for males, age 3 for females), age-4-and-older males and age-5-and-older females of a brood year have been absent in spawning station returns (Table 25).

Table 24. Numbers of chinook salmon from each treatment group from the 1991-brood year that returned to the Whitlocks Bay spawning station and to the fishery by year, age and sex. For each age category, the younger age corresponds to fish in the fishery and the older age corresponds to fish at the spawning station.

Treatment	Return location	Sex	Number returned by year and age						Total return
			1992 0-1	1993 1-2	1994 2-3	1995 3-4	1996 4-5	1997 5-6	
15.4-g, direct stocking	station	M		34	66				100
	station	F			89	10			99
	station	T		34	155	10			199
	Fishery		2	66	110	6	2		186
7.5-g, direct stocking of "runts'	station	M		2	5				7
	station	F			7	1			8
	station	T		2	12	1			15
	Fishery				2				2

Table 25. Percent of total return of chinook salmon from each treatment group from the 1991-brood year that returned to the Whitlocks Bay spawning station and to the fishery by year, age and sex. For each age category, the younger age corresponds to fish in the fishery and the older age corresponds to fish at the spawning station.

Treatment	Return location	Sex	N	Percent total returns by year and age					
				1992 0-1	1993 1-2	1994 2-3	1995 3-4	1996 4-5	1997 5-6
15.4-g, direct stocking	station	M	100		34.0	66.0			
	station	F	99			89.9	10.1		
	station	T	199		17.1	77.9	5.0		
	Fishery		186	1.1	35.5	59.1	3.2	1.1	
7.5-g, direct stocking of "runts'	station	M	7		28.6	71.4			
	station	F	8			87.5	12.5		
	station	T	15		13.3	80.0	6.7		
	Fishery		2			100			

Male chinook salmon from the 1991-brood year experienced the best growth of males from any chinook salmon brood year from 1986-1992 (Table 26). Males reached 2.6 kg at maturation at age 2 compared with 1.9 kg and 2.1 kg (spring-age-0-stocking groups only) for age-2 males from the 1990-and-1992-brood years, respectively. Growth of females from the 1991 brood year was also excellent, with age-3 females averaging 3.5 kg at maturation, second only to females from the 1990 brood year at 4.0 kg.

Table 26. Mean weight of chinook salmon from each treatment group from the 1991-brood year that returned to the Whitlocks Bay spawning station by year, age and sex.

Treatment		Mean weight (kg) at return by year, age and sex											
		1992 1		1993 2		1994 3		1995 4		1996 5		1997 6	
		M	F	M	F	M	F	M	F	M	F	M	F
15.4-g, direct stocking	N			34		66	89		10				
	Mean			2.6		4.3	3.5		3.4				
	SE			0.1		0.1	0.1		0.2				
7.5-g, direct stocking of "runts'	N			2		5	7		1				
	Mean			2.6		4.9	3.0		4.3				
	SE			0.1		0.2	0.2		---				

1992 Brood Year

The objective of CWT chinook salmon stockings for 1992-brood year fish was to determine the effect of size at stocking on initial survival of chinook salmon. In general, size and date at stocking are inter-related with larger fish being stocked later in the spring. However, we had the unique opportunity to stock two sizes of spring age-0 chinook salmon fingerlings on the same date in June of 1993. This allowed us to determine effects of stocking size on initial survival without the compounding effect of stocking date. Specifics on CWT groups from the 1992-brood year appear in Table 27.

Table 27. Chinook salmon coded-wire-tag-group statistics for tagging groups from the 1992-brood year. Treatment effects tested for the 1992-brood year included only size at stocking, as fish from both treatment groups were released on the same date.

Treatment	Number stocked	Kilograms stocked	Average size at stocking (g)	Stocking location	Stocking date
Direct stocking	22,959	307.7	13.4	Whitlocks Bay	5/25/93
Direct stocking	18,430	165.9	9.0	Whitlocks Bay	5/25/93

As illustrated by previous CWT stockings, a greater total number of the larger (13.4 g) spring-age-0-stocked fish returned to the spawning station than did CWT fish stocked at an average size of 9.0 g, the same day, when returns were weighted by numbers stocked ($P<0.05$ in both cases; Table 28). There was not a significant difference between the total number of chinook salmon returning to the spawning station or the fishery from the two 1992-brood-year-CWT groups, when returns were weighted by kilograms stocked. Chinook salmon from the 13.4-g CWT group contributed more to the creel, based on number stocked ($P<0.05$).

Table 28. Numbers of chinook salmon from each treatment group from the 1992-brood year that returned to the Whitlocks Bay spawning station and to the fishery by year, age and sex. For each age category, the younger age corresponds to fish in the fishery and the older age corresponds to fish at the spawning station.

Treatment	Return location	Sex	Number returned by year and age						Total return
			1993 0-1	1994 1-2	1995 2-3	1996 3-4	1997 4-5	1998 5-6	
13.4-g, direct stocking	station	M	2	50	116				168
	station	F			49	3			52
	station	T	2	50	165	3			220
	Fishery			69	75	25			169
9.0-g, direct stocking	station	M		23	62	1			86
	station	F			21	1			22
	station	T		23	83	2			108
	Fishery		2	35	48	19			104

The small difference in size at stocking appeared to affect survival before recruitment of stocked chinook salmon but did not affect patterns in maturation. No differences in pattern of maturation or percent total return to the fishery existed, for either sex, between chinook salmon stocked at 13.4 g and 9.0 g ($P>0.05$ in all cases: Table 29). The percentages of male chinook salmon from 1992- brood-year-spring-age-0-CWT groups maturing as jacks was similar to that for all CWT brood years except 1987 and 1988 (Tables 8 and 12, respectively) at 29.8% and 26.7% (Table 28). The percentages of CWT-group females from the 1992-brood year maturing as age-3 females in 1995 were the highest recorded for any CWT groups at 94.2% and 95.5% (Table 29). An interesting note is that 14.8% and 18.3% of total returns of 1992-brood-year-CWT groups in the fishery occurred as age-3+ fish while only 5.8% and 4.5% of the females returning to the station were age 4. Because males were absent from the spawning station at age 4, the majority of fish from the 1992-brood year-CWT groups in the fishery were females (Table 29). This suggests either substantial angler harvest of age-3+ females in the fishery or poorer homing ability of these fish to the spawning station than younger females.

The only difference in mean weight of chinook salmon at age at maturity between the two 1992-brood-year-CWT groups was for age-3 males maturing in 1995 ($P<0.01$; Table 30). In all other cases, no difference existed between mean weights at age at maturity for 1992-brood-year CWT groups.

Table 29. Percent of total return of chinook salmon from each treatment group from the 1992-brood year that returned to the Whitlocks Bay spawning station and to the fishery by year, age and sex. For each age category, the younger age corresponds to fish in the fishery and the older age corresponds to fish at the spawning station.

Treatment	Return location	Sex	N	Percent total returns by year and age					
				1993 0-1	1994 1-2	1995 2-3	1996 3-4	1997 4-5	1998 5-6
13.4-g, direct stocking	station	M	168	1.2	29.8	69.0			
	station	F	52			94.2	5.8		
	station	T	220	0.9	22.7	75.0	1.4		
	Fishery		169		40.8	44.4	14.8		
9.0-g, direct stocking	station	M	86		26.7	72.1	1.2		
	station	F	22			95.5	4.5		
	station	T	108		21.3	76.9	1.9		
	Fishery		104	1.9	33.7	46.2	18.3		

Table 30. Mean weight of chinook salmon from each treatment group from the 1992-brood year that returned to the Whitlocks Bay spawning station by year, age and sex.

Treatment		Mean weight (kg) at return by year, age and sex											
		1993 1		1994 2		1995 3		1996 4		1997 5		1998 6	
		M	F	M	F	M	F	M	F	M	F	M	F
13.4-g, direct stocking	N	2		50		116	49		3				
	Mean	0.3		2.1		3.4	2.9		2.5				
	SE	0.0		0.1		0.1	0.1		0.4				
9.0-g, direct stocking	N			23		62	21	1	1				
	Mean			2.1		3.1	2.9	2.8	2.9				
	SE			0.1		0.1	0.1	---	---				

Additional Findings

<u>Cost-Effectiveness</u>

Total numbers of chinook salmon returning to the spawning station and the fishery from 1989-brood-year-CWT groups were weighted by production costs to evaluate the performance of various stocking groups from a cost-benefit perspective. The cost of each fish returned to anglers from a CWT group could not be calculated, as not all CWT fish harvested by anglers were reported and fishery information for the years 1990-1992 was lacking. Therefore, the ratio of production costs (number stocked * individual fish cost) of CWT groups used in each comparison was used as the weighting factor. Estimated costs for the production of each individual fish and each CWT group are provided in Table 31.

Table 31. Estimated chinook salmon production costs for CWT groups and unweighted total returns to the spawning station and fishery for the 1989 brood year.

Size at stocking (g)	Stocking date	Number stocked	Cost per fish	Production costs	Total Return station	Fishery
8.6	6/8/90	29,019	$0.14	$4,062.66	106	114
56.7	11/1/90	7,704	$0.45	$3,466.80	108	93
156.4	4/24/91	9,232	$0.65	$6,000.80	381	177

In all cases, ratios of returns of larger-to-smaller-CWT-group-average weight at stocking were greater when only the number stocked was compared between CWT groups (Table 32.). When the total number of a CWT group returning to the spawning station or fishery was weighted by production costs, a sharp decrease in the ratio of returns between stocking groups existed. When production costs were figured in, differences in returns between CWT groups were diminished.

No differences existed in total returns to the fishery between-1989-brood-year-CWT groups, when numbers returned were weighted by production cost ($P>0.25$ in all cases). Therefore, if the same amount of money were spent raising spring-age-0, fall-age-0 or spring-age-1 fish, even though the numbers stocked would be different, the stockings would make the same contribution to the angler harvest. No difference ($P>0.10$) in total return to the spawning station existed between the spring-age-0 and fall-age-0-CWT groups when returns were weighted by production costs. The spring-age-1-CWT group from the 1989-brood year had higher total returns to the spawning station than did spring-age-0 or fall-age-0-stocked fish, when returns were weighted by production costs ($P<0.001$ in both cases). This may be due to the high number of males of the spring-age-1-CWT group that returned to the spawning station as jacks (Table 16).

Table 32. Ratios of weighted total numbers of chinook salmon returning to the spawning station and fishery for comparisons between CWT groups from the 1987- or 1989-brood years. Total numbers returning were weighted by number stocked and production costs of each CWT group.

CWT group comparison	Size at Stocking (g)	Weighted ratio of returns			
		by number		by cost	
		station	Fishery	station	Fisher
fall age 0 vs. spr. age 0	56.7 vs. 8.6	3.84	3.07	1.19	0.96
spr. age 1 vs. spr. age 0	156.4 vs. 8.6	11.30	4.88	2.43	1.05
spr. age 1 vs. fall age 0	156.4 vs. 56.7	2.94	1.59	2.04	1.10

Patterns in Growth and Maturation

Factors affecting patterns of maturation of chinook salmon are of interest as a fish's chance of contributing to the fishery increases as the length of time before maturation increases. Therefore, attempts were made to explain patterns of maturation observed for male and female chinook salmon. Only spring-age-0-CWT groups were used in these analyses.

The 1986- and 1987-brood-year-CWT groups were the only groups from which age-5 males returned to the spawning station (Figure 3). However, the lowest percent of males maturing as jacks occurred for the 1987- and-1988-brood-year stockings which matured in 1989 and 1990, respectively (Figure 3). Even though a low percentage of males from the 1988 brood year matured at age 2, no males from this brood year returned to the spawning station at age 5. The lowest percent of females maturing at age 3 occurred for the 1987-and-1988-brood-year-CWT groups which were 3 years old in the fall of 1990 and 1991, respectively (Figure 4). The lowest percent maturation at the earliest age at which maturation usually occurs (age 2 for males, age 3 for females occurred for the 1987-and-1988-brood-years for both sexes (Figures 3 and 4). As observed for males from the 1988-brood year, even though a low percentage of females from the 1988-brood year matured at age 3, no females from this brood year returned to the spawning station at age 5 or age 6 (Figure 4). Beginning with the 1989-brood-year-CWT groups, the percent of females from a brood year maturing at age 3 steadily increased while a corresponding decrease in percent maturation at age 4 occurred. No Age-5-and-older female chinook salmon returned to the spawning station from any brood year after the 1987-brood year (Figure 4).

Comparing the mean weight of mature age-2 males and mature age-3 females the with percent of a brood year of that sex maturing at that age, it appears that percent maturation may be related to growth and condition (Figures 5, 6). The two lowest mean weights at maturity of age-2 male chinook salmon occurred during 1989 and 1990 (1987- and 1988-brood years, respectively), as did the two lowest percent maturation values (Figure 5). The relationship between mean weight of age-3 female-chinook salmon at maturation and the percentage of females in a brood year maturing at that age is less clear (Figure 6). The lowest percentage of females maturing at age 3 occurred during 1990 and 1991 (1987 and 1988 brood years). Mean weight of age-3-female chinook salmon was much greater in 1991 than in 1990 but the percent of age-3 females maturing that year was the same as for 1990 (Figure 6). Also, the mean weight at maturity of age-3-female chinook salmon decreased after 1993, while the percent of females from a brood year maturing at age 3 continued to increase.

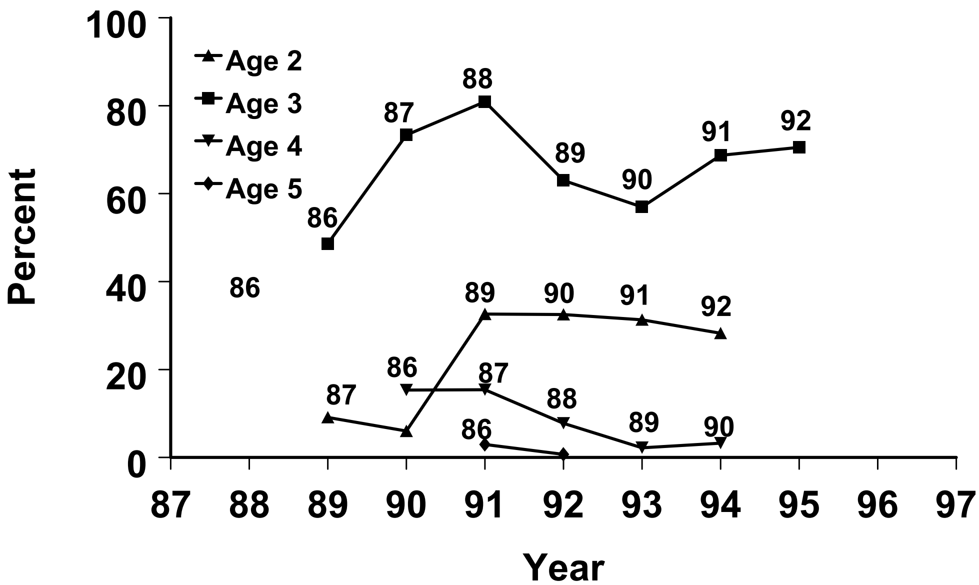

Figure 3. Percentage of male chinook salmon from a brood year returning to the Whitlocks Bay spawning station at various ages. Line labels refer to the brood year of fish that would be the indicated age that calendar year. Only spring-age-0-stocked-CWT groups were used in this analysis.

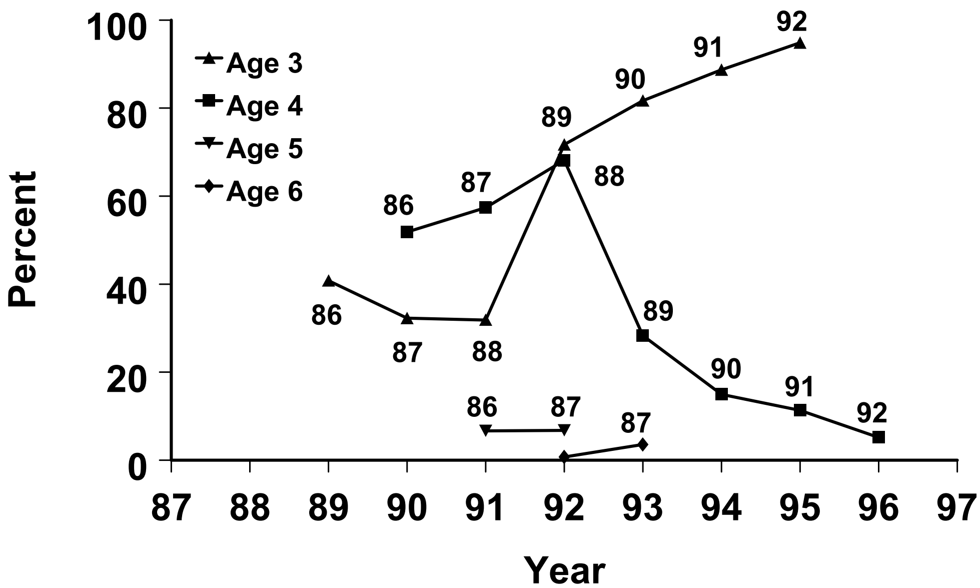

Figure 4. Percentage of female chinook salmon from a brood year returning to the Whitlocks Bay spawning station at various ages. Line labels refer to the the brood year of fish that would be the indicated age that calendar year. Only spring-age-0-stocked-CWT groups were used in this analysis.

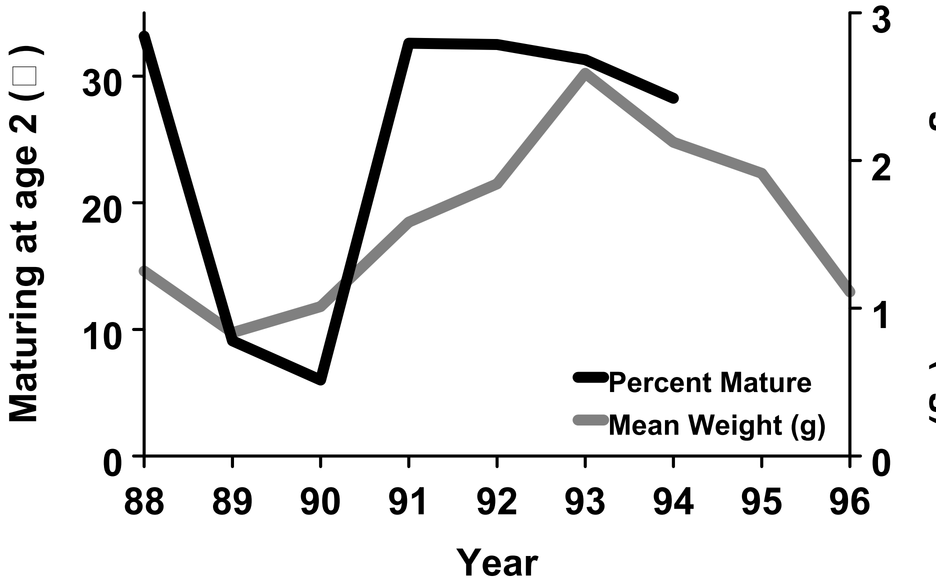

Figure 5. Patterns in percentage of males from a brood year returning to the Whitlocks Bay spawning station as mature, age-2 fish (jacks) and mean weight at return for CWT fish from the 1986 through 1992 brood years. Only spring-age-0-stocked-CWT groups were used in this analysis.

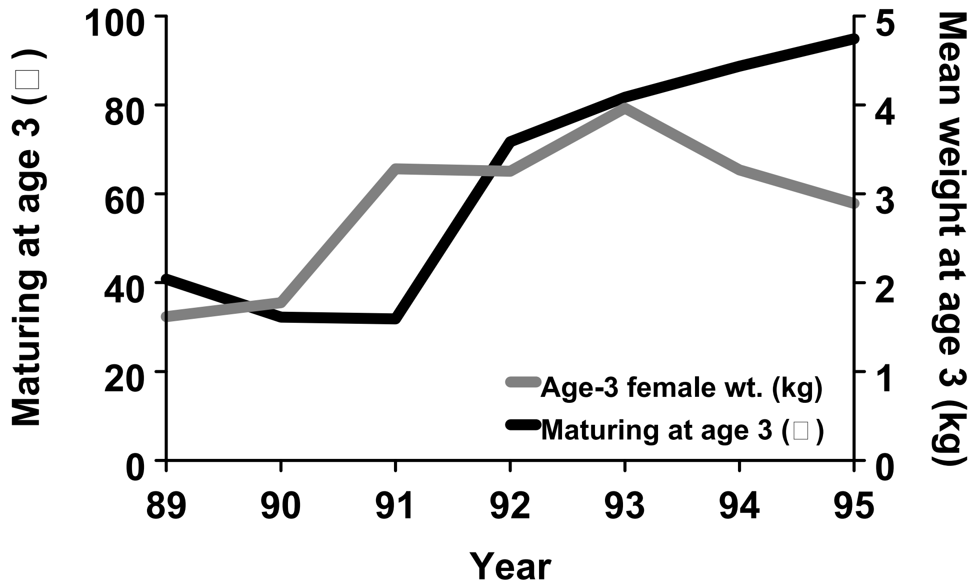

Figure 6. Patterns in percentage of females from a brood year returning to the Whitlocks Bay spawning station as mature, age-3 fish and mean weight at return for CWT fish from the 1986 through 1992 brood years. Only spring-age-0-stocked-CWT groups were used in this analysis.

Throughout the 1987-1996 period, a wide range in environmental conditions, chinook salmon growth rates and patterns of maturation occurred. This provided an excellent data set to test for correlation's between chinook salmon growth and condition and percent maturation at age 2 (males) or age 3 (females). In addition to fish length, weight and sex data collected at the Whitlocks Bay spawning station, information on the mean number of eggs per female was available. This information, in addition to the percentage of males of a brood year maturing as jacks, the percentage of females maturing at age 3 and *Wr* values for age-1-and-older fish in August-suspended-gill-net-samples, is provided in Table 33. Only spring-age-0-CWT groups were used in these analyses as raising fish to fall age 0 or spring age 1 prior to release affected patterns in maturation.

Table 33. Spring-age-0-CWT-chinook-salmon stocking group percent maturation at age and indices of growth or size at maturity for the 1986-1992 brood years maturing from 1988-1996. Percent maturation values from two or more CWT cohorts for a brood year were averaged. Mean weights and number of eggs per female values are for fish collected at the Whitlocks Bay spawning station at maturity and *Wr* values are from the August-suspended-gill-net survey.

Year	Percent maturing		Indices of Growth and Condition				
	Age-2 males	Age-3 females	Age-2 male weight (kg)	Age-3 female weight (kg)	Number of eggs/female	*Wr* previous Summer (m)	*Wr* summer of age 1+ (f)
88	33.2	.	1.3	.		80	
89	9.1	40.8	0.8	1.6	1842	77	80
90	6.0	32.3	1.0	1.8	1926	72	77
91	32.6	31.9	1.6	3.3	2352	94	72
92	32.5	71.7	1.8	3.3	3112	94	94
93	31.3	81.7	2.6	4.0	3884	100	94
94	28.25	88.7	2.1	3.3	3780	95	100
95	.	94.9	.	2.9	3737	.	95
96	.	.	.	.	.	.	.

A substantial amount of the variation in percent of males of a brood year maturing at age 2 was explained by the mean weight of mature age-2 male chinook salmon (P=0.10, r=0.67). From a plot of the data (Figure 7), it appears a threshold size may exist that age-1+ male chinook salmon must reach before they will become sexually mature the following fall. Mean weight (post-spawn weight) of age-3 female chinook salmon that return to the station was not significantly correlated with the percent of females from a CWT group maturing at age 3. However, the mean number of eggs taken per female during spawning operations was highly correlated (P=0.001, r=0.95) with the percent of females from a CWT group maturing at age 3 (Figure 8).

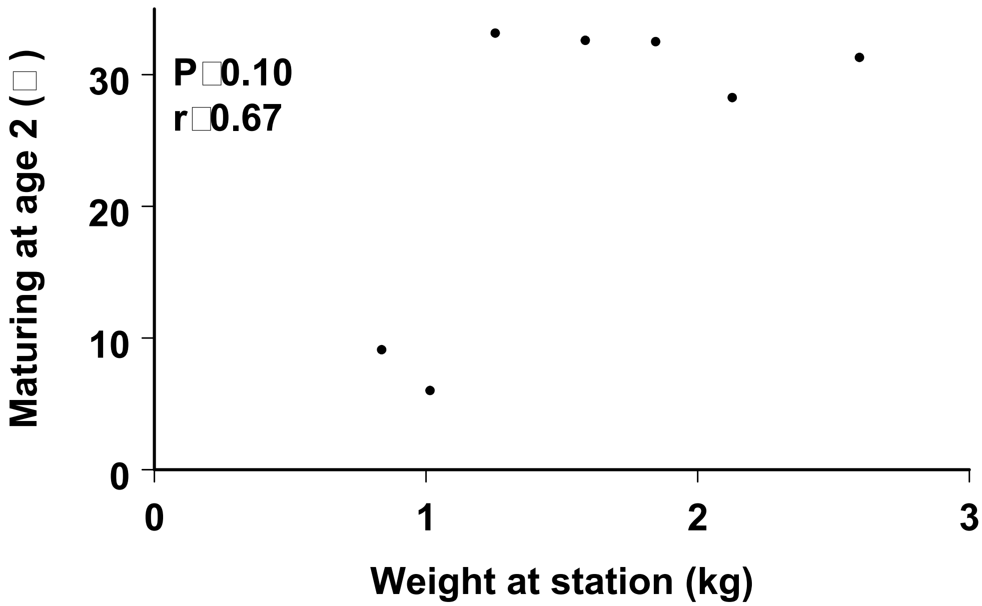

Figure 7. Plot of mean weight of age-2 male (jacks) chinook salmon at maturation and return to the Whitlocks Bay spawning station vs. percentage of males from the corresponding brood year maturing at age 2. Only spring-age-0-CWT groups were used in this analysis.

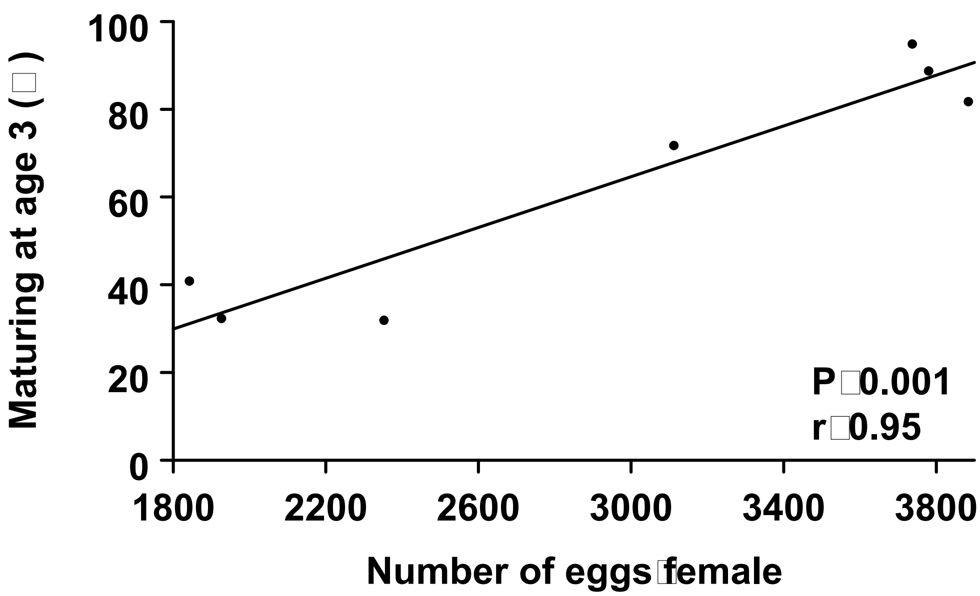

Figure 8. Simple linear regression analysis of mean number of eggs per female at maturation and return to the Whitlocks Bay spawning station and percentage of females from the corresponding brood year maturing at age 3. Only spring-age-0-CWT groups were used in this analysis.

Sixty-one percent of the variation in the percentage of males in a brood year maturing at age 2 that fall was explained by the *Wr* of age-1-and-older chinook salmon in August suspended gill net samples (P=0.10, r=0.78; Figure 9). Again, a threshold condition may exist that age-1+ male chinook salmon must reach before they will become sexually mature the following fall. For females, a strong correlation (P=0.001, r=0.96) existed between the *Wr* of age-1-and-older chinook salmon in the August suspended survey the summer a CWT group was age 1+ and the percent of females of that brood year maturing at age 3 (Figure 10, Table 34).

In turn, simple linear regression also showed significant correlations between age-1-and-older chinook salmon *Wr* values in the August suspended survey and the mean weight of mature age-2 male salmon with rainbow smelt catch-per-unit-effort values from the suspended survey (P=0.02, r=0.74 and P=0.01, r=0.82, respectively; Figures 11 and 12). Therefore, chinook salmon growth, as indexed by age-1-and older *Wr* and mean weight of mature age-2 males, was related to rainbow smelt density and patterns in chinook salmon maturation were also related to rainbow smelt density.

Table 34. Statistics for simple linear regressions between percent maturation and indices or growth or condition for spring age 0 stockings of the 1986-1993-brood-year-CWT groups. Percent maturation values are averaged over CWT groups from the same brood year and *Wr* values for age-1 and older fish are from the August-suspended-gill-net survey.

Independent variable	Dependent variable	d.f.	Probability >F	r	r^2
age-2 males maturing (%)	mean wt of age-2 males	6	0.096	0.675	0.455
age-3 females maturing (%)	mean number of eggs/female	6	0.001	0.948	0.898
age-2 males maturing (%)	age-1 and older *Wr*	6	0.038	0.781	0.609
age-3 females maturing (%)	age-1 and older *Wr* at age 1+	6	0.001	0.960	0.922

Discussion

Patterns in survival and contribution to the fishery and spawning station of CWT fish should be used with caution when making inferences about chinook salmon stockings in general, as the removal of the adipose fin resulted in 50% lower survival for fin clipped rainbow trout (O*ncorhynchus mykiss,* Nicola and Cordone 1973) and 39% lower survival for sockeye salmon when compared with unclipped counter parts (Weber and Wahle 1969). In addition to effects on survival, removal of the adipose fin may affect growth and potentially patterns in maturation. Fin removal on fingerling lake trout resulted in decreased growth in the wild (Schetter 1951). However, Barnes (1994) found no difference in feed conversion efficiency between adipose-clipped and unclipped trout in hatchery environments.

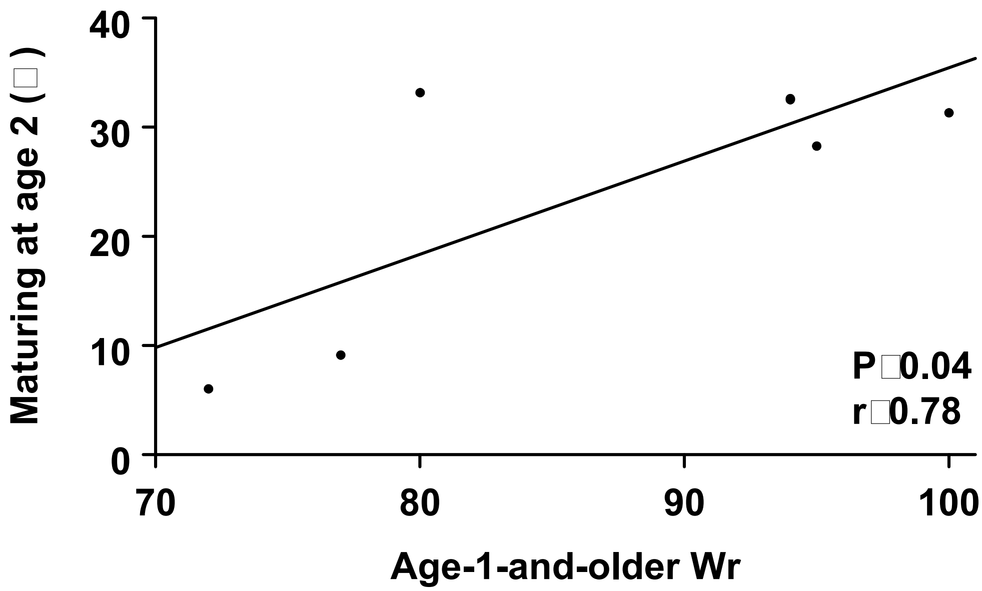

Figure 9. Simple linear regression analysis of chinook salmon relative weight (Wr) in the August gill net survey for age-1-and-older fish and percentage of males maturing at age 2. Only spring-age-0-CWT groups were used in this analysis.

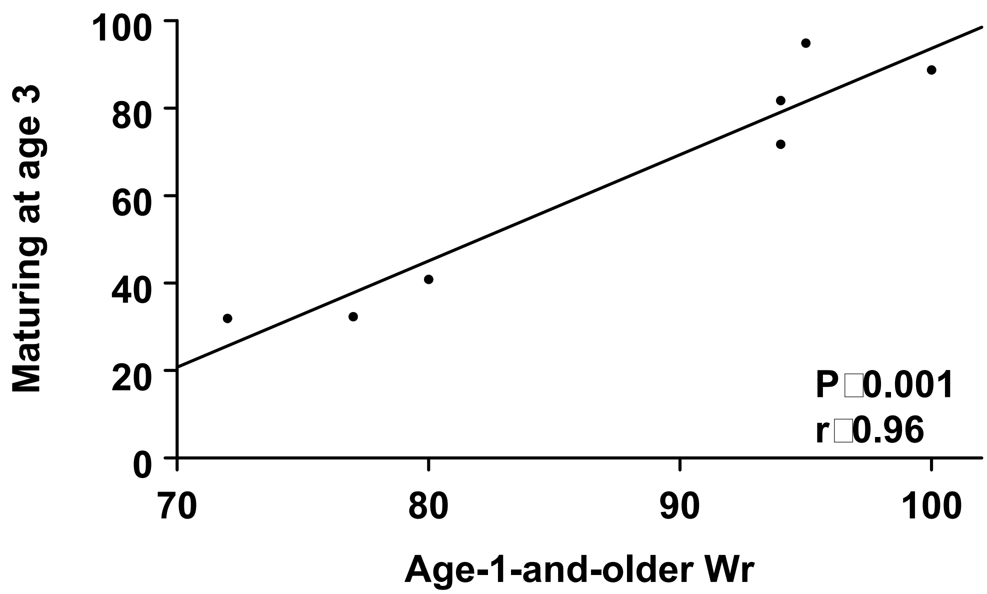

Figure 10. Simple linear regression analysis of chinook salmon relative weight (Wr) in the August gill net survey for age-1-and-older fish and percentage of females maturing at age 3. Only spring-age-0-CWT groups were used in this analysis.

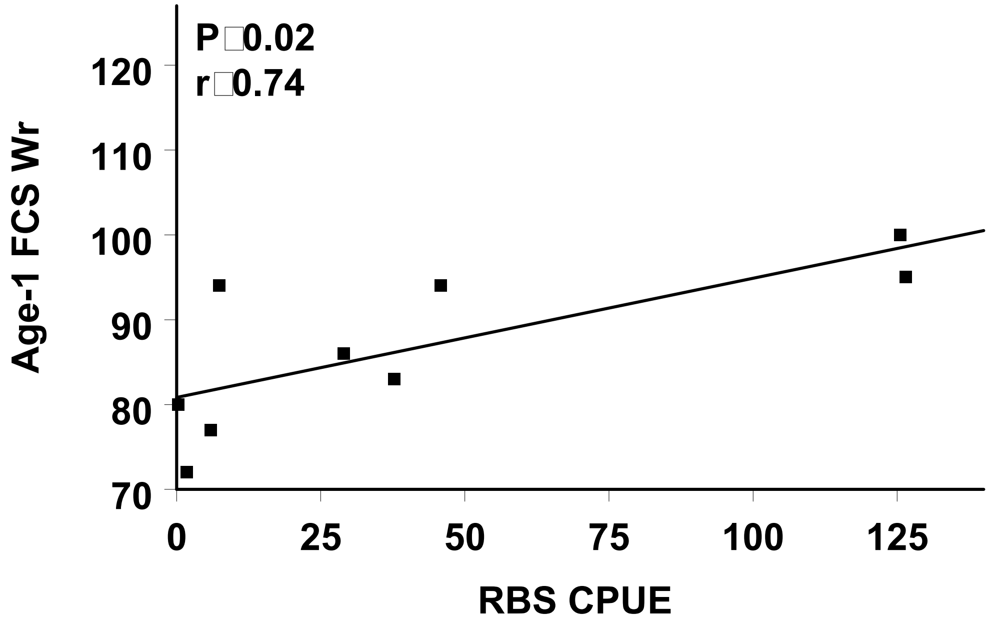

Figure 11. Simple linear regression analysis of rainbow smelt catch per unit effort (CPUE; No./net night) and mean Wr of age-1-and-older chinook salmon in August suspended gill net samples, 1988-1996.

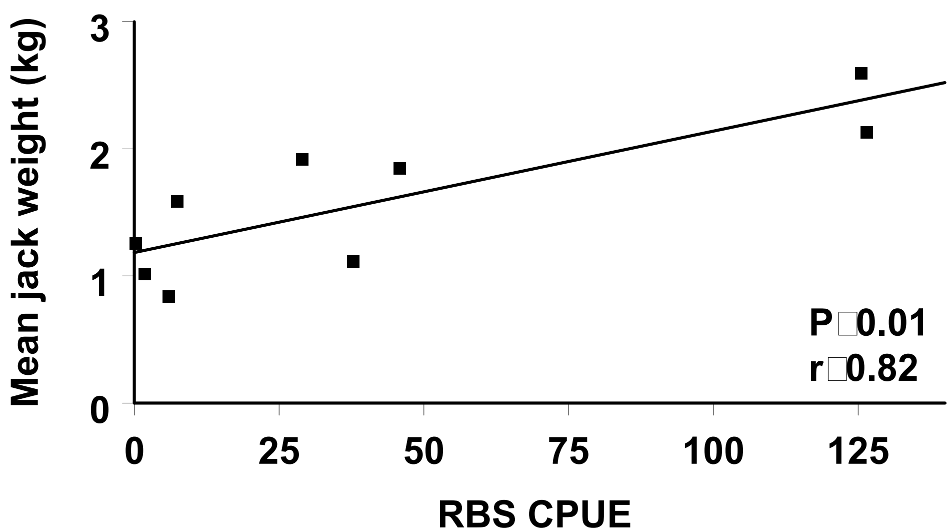

Figure 12. Simple linear regression of mean rainbow smelt catch per unit effort (CPUE) in August suspended gill net samples and the mean weight of age-2 (jack) chinook salmon at the Whitlocks Bay spawning station, 1988-1996.

Contribution to Fishery and Spawning Runs

For spring age 0-CWT groups from the same brood year, fish stocked at a larger average size, later in the spring, contributed more to the fishery and spawning runs than did fish stocked at a smaller average size, a month earlier. Even when stocked on the same date, as for the 1992-brood year, increasing the size of fish at stocking resulted in an increased contribution to the fishery and spawning runs, based on numbers stocked. When weighted by kilograms stocked however, no difference in contribution to the fishery or spawning runs was observed, as contribution per kilogram stocked was similar between spring age-0 CWT groups, irregardless of size at stocking. Other studies have documented positive correlations between kilograms of chinook salmon fingerlings stocked and subsequent returns of adults to hatcheries in the Pacific northwest (Wallis 1962; Junge and Phinney 1963). If the same number of kilograms of fish from stocking groups with different average weights were stocked, returns would have been similar, as was documented during our study.

Numbers of fish returned to the fishery, when weighted by number stocked, serves as an index to survival before recruitment into the fishable population. It is assumed that any difference in survival rates between spring age-0 stocking groups most likely occurs before recruitment of chinook salmon to the fishery, and that mortality from natural causes, except maturity, are similar for all groups of a CWT-brood year that have recruited to the fishery. As no difference in patterns of maturation was observed between spring age-0-CWT groups from the same brood year, patterns in natural mortality resulting from maturation should not differ between groups.

Spring-age-1-CWT-groups contributed more to the fishery and spawning runs at the Whitlocks Bay spawning and station than did spring-age-0-CWT groups from the same brood year, on a per-fish-stocked basis. However, on a kilogram-stocked basis, spring-age-0 stockings performed as well (1987 brood year) or better (1989 brood year) than spring-age-1 stockings. For Pacific Ocean runs of chinook salmon in California, it has been well established that fall-age-0 and spring-age-1 stockings contribute more to the fishery or hatchery than spring-age-0 stockings. Chinook salmon released from the Coleman Hatchery on the Sacramento River as spring age-0 fish had lower returns to the hatchery than fall-age-0 stocked fished from the same brood year (Cope and Slater 1957). Raising chinook salmon to spring age 1 before release from the Feather River Hatchery resulted in twelve times the return of fish to the fishery from this group than from another group released as spring-age-0 fish (Sholes and Hallock 1979).

Raising male chinook salmon to spring age-1 before stocking into Lake Oahe increased precocialness, for both the 1987 and 1989 brood years. This effect of rearing fish to older ages before release has also been observed for coho (Appleby and Seidel 1992) and chinook salmon (Zaugg et al. 1992) in the Pacific northwest. Over 98% of the males raised to spring age 1 before stocking into Lake Oahe matured at age 2 and were only present in the population for seven months. Therefore, mortality of males from these stockings was nearly 100% in the seven months after stocking and these males did not contribute substantially to the fishery.

Raising female chinook salmon to spring age 1 before release resulted in a later onset of maturity, as the percentage of the 1987-brood-year females maturing at age 4 increased. The delayed maturation of females raised to fall age-0 and spring age 1 before stocking contributed substantially to the strong representation of these females as large, age-3+ fish in the fishery in 1993. The large size of these females as age-3+ fish was also related to good growth rates during 1992 and 1993. A number of authors have documented increases in percentage of a stocking group returning to the fishery and spawning stations, as size and age at stocking increase (Cope and Slater 1957; Wallis 1962; Sholes and Hallock 1979; Bilton 1983; Hankin 1990). For coho salmon from Rosewall Creek, British Columbia, 88% of the variation in percentage of a stocking group returning to the fishery and hatchery was explained by size of fish at release (Bilton 1983).

If survival until recruitment to the fishery can be improved by raising chinook salmon until fall age 0 or spring age 1 before stocking, the same contribution to the population could be made by stocking fewer, older fish. However, if egg supply is not limited, stocking a larger number of less expensive, spring-age-0 chinook salmon, at the largest size available, would generate the same contribution to the fishery but would not tie hatchery space up for as long a time, increasing total hatchery production capabilities.

Imprinting Attempts

The difference in ratios of CWT groups in the fishery and ratios of CWT groups at the spawning station was used as an index to homing ability. The lower survival rate before recruitment to the fishery for morpholine-treated chinook salmon averaging 6.5 g at stocking was related to morpholine treatment. Morpholine-treated chinook salmon, averaging 14.3 g at stocking, did not experience the differentially higher mortality documented for morpholine-treated fish averaging 6.5 g at stocking. We have no explanation for the higher mortality rates of morpholine-treated chinook salmon averaging 6.5 g at stocking. The 35-day exposure to morpholine did not improve the homing ability of fish to the spawning station. This experiment should have been replicated to help clarify and substantiate results.

Morpholine exposure has been effectively used to improve the homing ability of rainbow trout (*Oncorhynchus mykiss*) and coho salmon (*Oncorhynchus kisutch*) in Lake Michigan (Scholz et al. 1975). However, there are no case histories that show morpholine treatment has improved chinook salmon homing ability. Scholz et al. (1975) and Cooper et al. (1976) stated that the key to successfully imprinting coho salmon with morpholine was to expose them to it during the pre-smolt and smolting periods. Also, fish used in studies by Scholz et al. (1975) were treated with morpholine and released at the same location where they were treated. In our study, chinook salmon were exposed to morpholine for 21 days at the hatchery, then transported to the spawning station where they were exposed to morpholine for an additional 14 days. Differences in chemical characteristics of the water supply at the hatchery and spawning station may also have contributed to the poor homing of morpholine-treated salmon if the pre-smolt and smolting periods were experienced at the hatchery and/or during transport to the spawning station.

In general, holding chinook salmon at the spawning station prior to stocking did not affect survival to recruitment into the fishery or ability to home to the spawning station. The one exception to this pattern occurred for the 1990-brood-year-CWT group held at the spawning station, which contributed more to the fishery than the group directly stocked into Whitlocks Bay.

Timing of stocking and transfer of chinook salmon from the hatchery to Lake Oahe and/or the subsequent stockings of these fish after holding them at the station may affect homing ability. If these events are not well timed with the pre-smolt and smolting developmental periods fish may not home well to the release site. Hatchery-reared rainbow trout that were stocked after smolt transformation occurred, had poor return rates to the release site and an increased incidence of straying than those released at the optimum time, in Lake Michigan (Scholz et al. 1978). For Lake Oahe chinook salmon, Hoffnagle (1994) documented that a sufficient change in water chemistry could induce smoltification. This should theoretically occur when fish are stocked from transport trucks (hatchery water) into Whitlocks Bay or spawning station raceways.

Though not directly estimated during this study, chinook salmon in Lake Oahe appear to be very poor homers, as many stray chinook salmon are observed in the backs of embayments downstream from Whitlocks Bay each fall. In the lower Columbia River, Washington, between 72.5% and 90.1% of chinook salmon from various stocks returned to their natal stream for spawning (Quinn et al. 1991). The percentage returning to Whitlocks Bay is probably only a fraction of these values. Possible reasons for the poor homing ability of Lake Oahe chinook salmon include a lack of imprinting to Whitlocks Bay, rearing practices, heredity effects on homing behavior, age at maturity and the effect of high shoreline development on homing success. Possible factors influencing a lack of imprinting to Whitlocks Bay have already been discussed. It is not surprising that homing ability of Lake Oahe chinook salmon is so poor as Whitlocks Bay is similar to many other bays on Lake Oahe and the flow created at the spawning station if far from that generated by the type of natural stream, Pacific-northwest chinook salmon evolved with.

The chinook salmon population of Lake Oahe was established from eggs taken from Lake Michigan fish, which in turn were established from eggs from chinook salmon stock from a Pacific northwest river. Work by McIsaac and Quinn (1988) established that a hereditary component of homing behavior exists, in addition to a learned component. In a study of effects of releasing a group of chinook salmon at a location downstream from their ancestral spawning area, McIsaac and Quinn (1988) observed that only 58% of fish returned to their release location, while 42% were either recaptured on their way to or at their ancestral spawning ground. The strain of chinook salmon in Lake Oahe originated in the Toutle River, Washington, and eggs used to establish and maintain the Lake Oahe population were obtained from the Manistee River, Michigan. The chinook salmon stock used to establish the Lake Oahe population has only been removed from it's native environment for approximately 30 years. Therefore, the heredity component of the homing ability of Lake Oahe chinook salmon probably is not tied to the chemical or geographic characteristics of Whitlocks Bay but to other chemical and geographic characteristics.

It has been well documented that increases in the age at maturity of chinook salmon are related to an increase in the incidence of straying (Quinn and Fresh 1984; Quinn et al 1993; Unwin and Quinn 1993). For New Zealand stocks of chinook salmon, straying rates were positively correlated with age at return (Quinn and Fresh 1984; Quinn et al 1993). No differences in straying rates were noted between sexes or between stocking groups of different sizes stocked on different dates (Unwin and Quinn 1993).

The high shoreline development of Lake Oahe may present an obstacle to chinook salmon trying to home to Whitlocks Bay. It is generally accepted that two phases of salmon homing occurs during spawning migrations. Salmon first return to the generalized region of their natal stream and then search and find their natal stream (Scholz et al. 1975). The shoreline development index for Lake Oahe is extremely high at approximately 26.4. Unlike navigating in the Pacific ocean, where fish migrate from the open ocean to a region of the coastline to begin searching for a natal stream, chinook salmon in Lake Oahe must navigate through a winding reservoir with many side bays where they may become lost in their attempt to return to Whitlocks Bay. Once in the backs of bays, chinook salmon appear to stay there, rather than returning to the mainstem of the reservoir to get their bearings. Hoffnagle (1994) suggested water chemistry may differ little among embayments in Lake Oahe. This, in conjuction with a lack of local runoff from feeder creeks in the the fall, may hamper a salmon's ability to home to Whitlocks Bay.

Cost Effectiveness of Stocking Strategies

The spring-age-1-CWT group from the 1989-brood year had higher total returns to the spawning station than did spring-age-0 or fall-age-0-stocked fish, when returns were weighted by production costs. However, almost all the males from this CWT stocking group returned to the station at age 2.

No differences existed in total returns to the fishery between 1989-brood-year-CWT groups, when numbers returned were weighted by production cost ($P>0.25$ in all cases). Therefore, if the same amount of money was spent raising spring-age-0, fall-age-0 or spring-age-1 fish, even though the numbers stocked were different, the stockings would contribute equally to the fishery.

Both production cost and kilograms stocked reduce the magnitude of differences between numbers of fish returning from two CWT groups stocked at different sizes at different times of the year because, for the same number of fish, production costs increase as rearing time and size of fish increase.

Growth and Maturity

Differences in size at stocking of spring age-0 fish did not affect maturation patterns. As growth rates improved during 1992 and 1993, age-4+ fish, in the population in the summer, and age-5 fish, at the spawning station, were absent. This likely resulted from most fish maturing at earlier ages because of good growth and condition and not a change in heredity affects on age at maturation.

As previously discussed, raising male chinook salmon to spring age 1 before stocking into Lake Oahe resulted in an increase in the percentage of males maturing at age 2 to 98-100%. An increase in percent maturation at age 2 was also documented for coho salmon (Appleby and Seidel 1992) and chinook salmon (Zaugg et al. 1992) in the Pacific northwest. However, the percentages of males maturing at age 2 (jacks) from spring-age-0 and spring-age-1 stockings from the Little White Salmon National Fish Hatchery, Washington were <1% and 16%, respectively (Zaugg et al. 1992). Percent of males maturing at age 2 (jacks) from spring-age-0 and spring-age-1 stockings into Lake Oahe for the 1987-brood year were 9.1% and 100% , respectively. Percent of chinook salmon males maturing at age 2 (jacks) for spring age-0, fall-age-0 and spring-age-1 stockings into Lake Oahe for the 1989-brood year were 32.6%, 31.7% and 98.3%, respectively. For Lake Oahe, stocking chinook salmon at fall age 0 did not increase the percentage of males maturing at age 2. Ratios of males to females returning to the Whitlocks Bay spawning station, from spring-age-0 stockings from the 1987- and 1989-brood years ranged from 1:1.3 to 2.5:1, while those for spring-age-1 stockings were 10.2:1 and 3.6:1 for the 1987 and 1989 stockings, respectively.

Fall age-0 stockings did not cause an increase in percentage of males maturing at age 2, but did cause a higher percentage of females maturing at age 4. However, the high percentage of females maturing at age 4 from the fall-age-0-stocked-CWT group may be due to slower growth. This fact, in conjunction with higher return rates to the station and fishery than spring-age-0 stocked fish when weighted by numbers stocked, makes fall-age-0 stockings the best option to increase the number of age-3+ fish in the fishery.

Beginning with the 1989-brood year, the peak in female percent maturation, for spring age-0 stocked fish, occurred at age 3 (1992), rather than at age 4, as in previous years. As a larger percentage of fish of both sexes have matured at the earliest age at which maturity is generally reached (age 2 for males, age 3 for females), age-4-and-older males and age-5-and-older females of a brood year have been absent in returns to the spawning station.

Fish from fall-age-0- and spring-age-1-Lake-Oahe stockings tended to be smaller on average, at age at maturity, than fish from spring-age-0-stockings from the same brood year. Smaller size at maturity of spring-age-1-stocked chinook salmon, when compared with spring-age-0-stocked fish from the same brood year, has been documented in the Pacific northwest (Warner et al. 1961; Wallis 1968; Zaugg et al. 1992). Spring age-1-stocked fish in these studies missed one year of ocean growth (Warner et al. 1961) and were generally the size of fish one brood year younger at a given age (Wallis 1968). It seems contradictory that males stocked at spring age-1 would be smaller at age 2 in Lake Oahe than their spring age-0 stocked counterparts but have almost a 100% maturation at age 2. However, both rearing history and growth rates experienced affect age at maturation. Rearing history is responsible for the high percentage of males stocked as spring-age-1 fish maturing at age-2, while changes in percentages of males maturing at age-2 and of females maturing at age 3, from spring age-0 stockings, are related to growth and condition.

Females from the 1989-brood-year-spring-age-0-CWT group generally matured a year earlier than females from the 1989-brood-year-fall-age-0 and spring-age-1 stockings. This may be related to growth as fall-age-0 and spring-age-1 fish were generally smaller at age than there spring-age-0 stocked counterparts. Hankin (1990) also documented smaller sizes at age for chinook salmon raised for longer time periods before release and a corresponding older age at maturity of females from these releases.

Appleby and Seidel (1992) discovered that size-and-age-at-stocking, and parentage affects on percent of male coho salmon maturing at age 2 may be cumulative. The results of our study suggest that growth rate and condition may be an additional cumulative affect regulating the percentage of males maturing at age-2 in Lake Oahe.

Strong correlations between percent of males or females maturing at the youngest age maturity is generally reached and age-1 and older *Wr* in the August suspended gill net survey are not surprising, as the condition of a fish the summer before spawning, (males) or two summers before spawning (females) probably triggers the onset of maturity. The eggs of female chinook salmon start developing before their last year of life and good growth during the two years prior to spawning is probably required to allow a fish to be of the proper size and condition to mature. It is generally believed that as the size of female salmon increases, so does the number of eggs and egg size (Fowler 1972). However, in Lake Oahe, the number of eggs per female and egg size did not change significantly with increasing fish length (Barnes and Cordes 1993). Although, the number of eggs per kilogram of female weight and fish length were moderately correlated (r^2=0.44). It is not surprising that the mean post spawn weight of age 3 female chinook salmon was not significantly correlated with percent maturation of females at age 3 as these weights do not include the strongest indicator of condition, that being egg numbers and size.

Data points in Figures 9 and 10 are grouped into two clumps supporting the hypothesis that instead of a positive linear relationship between growth and maturity, a threshold size and/or condition level must be attained before the onset of maturity is triggered. Because maturation is a function of both fish age and size, Hankin (1990) has suggested that age-specific thresholds in fish size must be reached before the onset of maturity occurs.

Using chinook salmon condition during summer to predict percent of a brood year maturing at age 2 (males) or age 3 (females) will enable us to predict the percent contribution of a brood year to the fishery and spawning runs in future years. This information, in addition to information on causes of mortality other than maturity, will allow us to inform anglers about the current and future status of the chinook salmon fishery.

Management Recommendations

1. If the chinook salmon egg supply is not limited, stocking a larger number of less expensive, spring-age-0 chinook salmon, at the largest size available (15 g), would generate the same contribution to the fishery as stocking fewer fall age-0 or spring age-1 fish, without tying hatchery space up during the summer and fall months.

2. If the chinook salmon egg supply is limited, some of the chinook salmon being reared from a brood year should be raised until fall age-0 before stocking to take advantage of the higher survival of fish stocked at fall age 0 rather than spring age-0. The problem of increased precocialness of males was not evident for fall age-0 stocked fish, as it was for spring age-1 stocked fish. However, fall-age-0-stocked fish may be smaller at maturation and therefore, have fewer eggs per female than spring-age-0 stocked fish.

3. Chinook salmon should be directly stocked into Whitlocks Bay, rather than being held at the spawning station prior to release. Chinook salmon should not be released near Oahe Dam as a large percentage of salmon stocked near Oahe Dam probably leave the system, through inter-basin transfer as age-0 fish, never contributing to the fishery.

4. Attempts should be made to identify aging structures and techniques that will allow age frequencies representative of all chinook salmon in spawning runs, angler harvest and the population to be generated. Currently, CWT chinook salmon are the only fish we can accurately age. Unfortunately, age frequencies of CWT chinook salmon are not representative of the whole population as CWT fish are generally raised to specific sizes while a great deal of variation in size at stocking exists for fish not containing CWTs. Therefore, initial survival of non-tagged chinook salmon may differ from CWT salmon and the contribution of non-tagged and tagged salmon to year class strength may be different.

5. Oxytetracycline hydrochloride (OTC) is commonly used to mark large groups of salmonids and leaves very good marks on bones and fin rays. If fish are to be sacrificed, this could be a possible method for marking large groups of fish.

6. Incorporate relationships between chinook salmon condition during summer and the percent of a brood year maturing at age 2 (males) or age 3 (females) into attempts at predicting the percent contribution of a brood year to the fishery and spawning runs in future years.

7. If using CWTs to mark a treatment group of chinook salmon, at least 20,000 fish should be marked in each group to allow meaningful data interpretation to be possible.

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Appendices

Appendix 1. Coded-wire tagged chinook salmon stocked in Lake Oahe, 1987-1996. Number stocked is corrected for tag loss.

Date Stocked	Location	Size (number/lb.)	Number Stocked	Treatment	Purpose
04/15/87	Whitlocks Bay	70.0	29,602	21 day morpholine imprint at Blue Dog and held 14 days at Whitlocks station.	Evaluate chemical imprinting and stocking size.
04/15/87	Whitlocks Bay	70.0	29,910	Held at Whitlocks station 14 days.	
05/18/87	Whitlocks Bay	32.0	19,876	Held at Whitlocks station 14 days.	
05/18/87	Whitlocks Bay	32.0	20,188	21 day morpholine imprint at Blue Dog and held 14 days at Whitlocks station.	
05/12/88	Whitlocks Bay	64.0	64,508	Held at Whitlocks station 10 days.	Evaluate stocking size and identify Oahe stock.
05/31/88	Whitlocks Bay	30.0	53,815	Held at Whitlocks station 14 days.	
04/12/89	West Shore	3.3	6,235	None	Evaluating yearling stocking size and stocking location. Evaluate adult return rate of smolts held at Whitlocks station vs. those stocked directly.
04/13/89	Whitlocks Bay	3.3	6,250	Held at Whitlocks station 4 days.	
05/25/89	Whitlocks Bay	43.8	28,999	Held at Whitlocks station 10 days.	
06/05/89	Whitlocks Bay	34.4	30,164	None- directly stocked into Whitlocks Bay from hatchery	
06/08/90	Whitlocks Bay	53.0	29,019	Held at Whitlocks station 25 days	Evaluate stock size and identify known age fish. Evaluate fall stock and identify know age fish. Evaluate stock size and identify known age and hatchery source. Evaluate Oahe Tailwater stocking.
11/01/90	Whitlocks Bay	8.0	7,704	Held at Whitlocks station 15 days.	
04/24/91	Whitlocks Bay	2.9	9,232	None - direct stock	
03/08/91	Oahe Tailwaters	3.0	5,254	None	
05/15/91	Whitlocks Bay	45.0	17,850	Held at Whitlocks station 14 days.	Compare adults return rate from smolts held and stocked from Whitlocks station. Compare adult return rate from smolts held and stocked from Whitlocks station.
05/16/91	Whitlocks Bay	46.2	19,242	None - direct stock.	

Coded-Wire Tagged Chinook Salmon stocked in Lake Oahe, 1987-1996 (continued).

Date Stocked	Location	Size (number/lb.)	Number Stocked	Treatment	Purpose
05/27/92	Whitlocks Bay	29.5	30,193	None - direct stock.	Identify known age fish.
05/27/92	Whitlocks Bay	60.3	2,623	None - direct stock	Determine stocking success and survival of “runts”.
05/25/93	Whitlocks Bay	33.9	22,959	None - direct stock	Identify know age fish. Compare stocking sizes of 34/lb. with 51/lb.
05/25/93	Whitlocks Bay	50.6	18,430	None - direct stock	
05/23/94	Whitlocks Bay	29.6	47,973	None - direct stock	Identify known age fish.
05/30/95	Whitlocks Bay	27.9	48,469	None - direct stock	Identify known age fish.
05/28/96	Whitlocks Bay	32.5	46,397	None - direct stock	Identify known age fish.